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PALEOGEOGRAPHICAL STUDIES OF PEAT BOGS IN NORTHERN JAPAN

By

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Contents

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I. Introduction

1. Paleogeographical Significance of the Studies of the Peat Bog.

Peat is a natural deposit composed of plant remains which are decomposed incompletely. Peat bog is a natural peat forming area. However, both definitions should naturally be different according to the study fields related to peat and peat bog. According to C. A. WEBER's definition the peat bog must have a peat layer of at least 20 cm thickness after drainage. E. GRANLUND has also given a definition of a peat bog as a poorly drained area covered with a peat layer of more than 40 cm in thickness under natural conditions. The problem of thickness of the peat layer is particularly important because of the possible effect of the peat layer on plowing or cultivating, or whether a peat bog is valuable as a peat-producing place or not. The *moor* in European languages means not only a peat bog in the geological sense, but also a bog without a peat layer in the phytogeographical sense. To avoid such confusion in this paper the author as a rule uses *peat bog* for *moor* having the geological meaning. Now the author considers that a place accumulating peat should be called a peat bog, whether the peat layer is thin, or whether hydrophytes are not even growing there. From the paleogeographical view-point the fact that the peat layer exists there is more important than the thickness of the layer, because the latter is easily diminished by such processes as decomposition, erosion, compression, shrinking by dehydration, and so on. The reason why the author is concerned with the fact of the peat layer, not its thickness, is based on this respect. Moreover, from the same point of view, the author defines the peat as a natural deposit that is composed of plant remains only, or at most mixed with a very small amount of mineral matter like clay. Accordingly the peat must be clearly distinguished from clayey peat, peaty clay, or organic clay, which the author classified according to the mixture ratio of clay and organic matter. But *peat* in the other authors' literature quoted in this paper must be regarded as the synonym of the peat defined by the author, when the character of the deposits described as peat in the literature is not

clear.

It was in the middle of the 17th century that the Russian people's attention was directed to peat bogs as the agricultural field or fuel digging field. During the latter half of the 18th century the studies of bog vegetations were done accompanying investigations for utilizing peat bog. It was, however, not before the 19th century that the peat bog was treated by many investigators as an object of pure science. The studies concerning the ecological succession of the moor achieved by W. KIND, R. RENNIE, J. J. S. STEENSTRUP, and so on developed to A. BLYTT's theory of the climatic change during the postglacial age; afterwards the latter was modified by R. SERNANDER. Thus the climatic sequence of the postglacial age in North Europe, so-called BLYTT-SERNANDERS' theory, was established. Since then the significance of the peat layer for the Quaternary researches came to be highly evaluated by many investigators. According to F. SOLGER the investigators who had studied peat bogs from the geographical point of view until 1904 were RAMANN, WALTHER, FRÜH, SCHRÖTER, FROH, and others. He also emphasized in the lecture at the Berlin Geographical Society of May 1905 that the studies of the peat bog had chiefly been made by botanists up to that time, and then the biological and chemical characters of peat and peat bog had been made clear; and he also said that from that time such a study should be done from the geographical or geological point of view. He has mentioned that it was the important objective of studies of peat to know the topographic and climatic conditions that controlled peat forming, or to make clear the environment during the coal forming period being based on the results of studies of peat. Moreover, he appealed to the geographers to take an interest in such problems. In 1916 the pollen analysis was established by L. von POST as one of the scientific research methods for the Quaternary problems. With the varve-chronological method devised by G. de GEER the establishment of the pollen analysis was really an epoch-making event, in the research history of the Quaternary period. By application of both methods the researches on the earth history of the Quaternary period in the world have been expanded and deepened rapidly. For some years around 1930 the theories on the peat and the peat bog were almost compiled systematically, and the regional descriptions of peat bogs and their developmental histories in the world were achieved by the *Moorgeologen*, such as K. von BÜLOW, W. S. DOKTUROWSKY, V. AUER, A. P. DACHNOWSKI-STOKES.

In Japan at the end of the 19th century the first scientific description of the peat bogs was published by an agriculturalist, H. TOJO; that was the treatise on the genesis of the peat bog at Kakunodate Basin, North Honshū. It was, however, D. SATO, geologist, who described for the first time a peat bog from the geographical point of view, as Solger says. He observed peat layers at Kamegaoka, North Honshū, which place was famous for the discovery of neolithic remains, and said, "From these results we can learn the geological change of this area during the neolithic age. The occurrence of peat proves sufficiently that the climate at that time was so moist that the bog vegetation might grow, and at the same time it was so cold that the decomposing of plant

remains might not be active." In the same year in *The Journal of the Geological Society of Japan* he reviewed and criticized the method of determination of age by stratification of the peat layers. As above-mentioned, he had a deep interest in the peat layers. We can also find descriptions of the peat layers as a geological formation in the explanatory texts of the geological maps of a scale of 1 : 200,000 made at that time, such as Chiba, Ishinomaki, Akita, and Aomori sheets. In 1931 T. KOBAYASHI referred to the peat layers in the coastal regions of the Yellow Sea when he treated the geomorphic development of the Korean Peninsula, and he regarded the peat layers as a proof of the submergence of land. However, until the end of World War II the studies of the peat bog had been made chiefly by botanists. The phytosociological and phytoecological studies of the peat bogs in Japan by H. NAKANO, Y. YOSHII and others may be regarded as representative works. The pollen analytical method was first introduced to Japan by D. NUMATA in 1929, about 15 years later than it was tried in Europe. Afterwards this method applied to the study of various peat bogs in Japan by T. YAMAZAKI, T. JIMBO, K. MIYAI, S. HORI, J. NAKAMURA and others. Among them, YAMAZAKI has synthetically treated on the climatic changes during the latest geologic age in Northern Japan (including Sakhalin

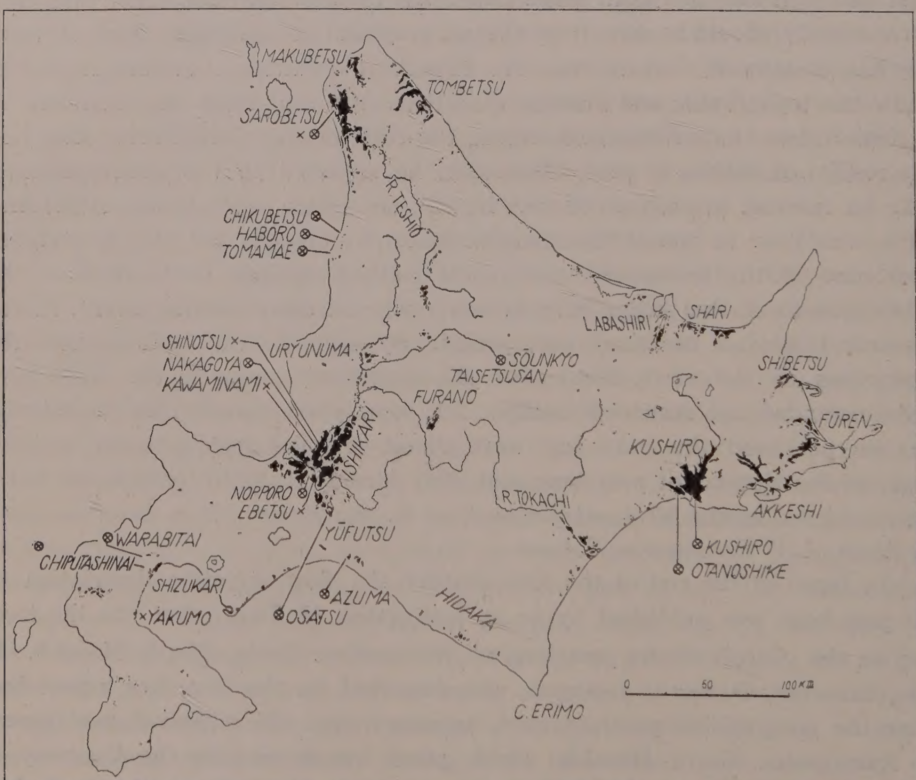

Fig. 1. Distribution of the peat bogs in Hokkaido (After the Hokkaido Agricultural Experiment Station).

Sampling localities for pollen analysis: ⊗, Pleistocene peat samples; ×, buried Holocene peat samples.

Is.) for the pollen analysis, and made clear the climatic changes in Northern Japan since the Pleistocene epoch by the mixed ratio between *Abies* and *Picea*. S. Hori has made ecological studies of the peat bogs in the mountainland of Central Honshū and treated the climatic changes during the Holocene epoch by pollen analysis. Meanwhile, about 1930 the Hokkaido Agricultural Experiment Station surveyed and made detailed distribution maps and descriptions of peat soils (Fig. 1). The work of K. Uragami and S. Ichimura, *The Characteristics and Agriculture of Peat Land*, is one of the most excellent treatments of the subject of peat and the peat bog in general and the character of agriculture on the peat bog in Japan. It was after World War II that the materials related to the stratigraphy of the peat layers in Hokkaido collected by Uragami and his collaborators were published for the first time. Meanwhile, it was after World War II that alluvial plains were taken seriously by geomorphologists in Japan as an object of study. We can point out two remarkable works related to the plains before 1945; namely, one of them was the studies of the Kanto Plain by T. Tōki, the other the studies of the Manchurian Plain and Inner Mongol by F. Tada. Since 1945 various problems of the plains in our country have been taken by F. Tada, Y. Ogasawara, S. Nakano, H. Iseki and others. After the war many relics in the plains have been excavated by archeologists, and some geographers have worked with them and attempted to reconstruct the natural environment at that time around the relics. The geology of the alluvial plains had been made clear with the progress of the reconstruction works in areas damaged by the war. The floods that often occurred after the war also gave chances to make physical geographers' interests turn to the alluvial plains. Through such experiences of the investigation we have recognized that one of the important deposits consisting of the alluvial plains is the peat.

The distribution of the peat bogs in the world is almost limited to the Northern hemisphere. The intensive peat forming areas defined by M. N. Nikonov, that is, the areas accumulating peat of tens and hundreds of tons per hectore are distributed in the forest zone from the Yenisei to Ireland in Eurasia and from the coast of the Atlantic Ocean to the Cordilleras in North America, the low region of the Amur and the west coast region of the Kamchatka Peninsula. The total dimension of these peat bogs including the intensive peat forming areas is 9,000,000 km^2, covering an area of 6% of all the land on the earth. The intensive peat forming areas are nearly correspondent to the regions where the value of the humidity coefficient (annual precipitation : annual evaporation) is more than 1, excluding the region under the permafrost-forming conditions, and are in the sub-arctic zone and part of the temperate zone. The conspicuously good coincidence between the intensive peat forming areas and the glaciated regions in the Quaternary period has been emphasized by Nikonov, Schreiber and others (Fig. 2). The *Urstromtäler*, glacial troughs, terminal basins, shallow hollows on the moraines, lowlands around eskers or drumlins, and so on are the most adequate places for the formation of a peat bog, and in topographies where those are dominant the most intensive peat

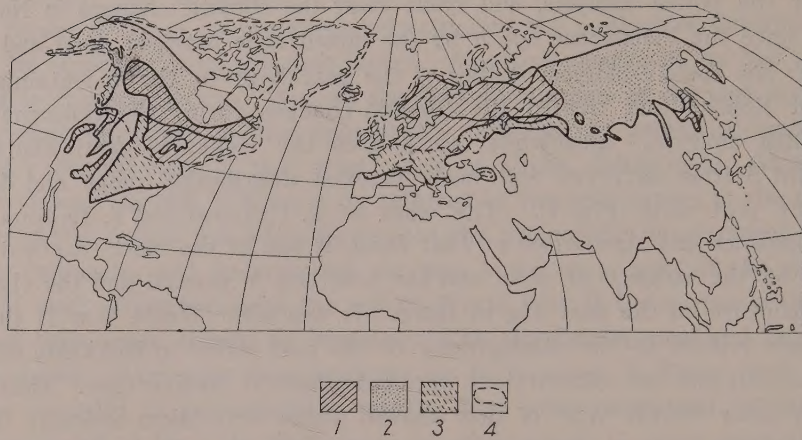

Fig. 2. Map showing that the intensive peat forming areas of the world well coincide with the Quaternary glaciated areas and the taiga zone. 1, intensive peat forming areas; 2, taiga zone; 3, temperate forest zone; 4, Quaternary glaciated areas.

forming areas in the world are found, caused not always by topographic but also climatic and pedologic conditions.

Taking the mean monthly temperature from May till October as one of the factors which control the peat production, the isotherm of 20°C of the mean temperature of July approximately coincides with the southern limit of the intensive peat forming areas, and Hokkaido is situated within this limit (Fig. 3). It is no doubt that Hokkaido is the most intensive peat forming area in

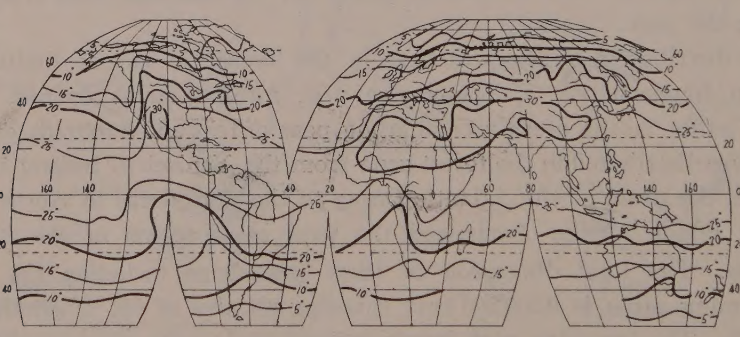

Fig. 3. Mean temperature of July.

Japan, though the whole aspect of the peat bogs in Japan has not completely been made clear. Therefore, we can only say that the isotherm of 20°C of the mean temperature of July well coincides with the southern limit of the intensive peat forming areas in Japan. Also the isotherm of 25°C of the mean temperature of July that runs east to west nearly in the middle of Honshū is regarded as the southern limit of the peat bogs in the lowlands[1] of Japan. Japan is one

1) "Lowland" used here is an alluvial plain of less than 100 m in elevation.

Fig. 4. Distribution of the peat bogs in Japan (Scale: 1/10,250,000).

Legend: 1, alluvial plains; 2, Quaternary volcanic rocks; 3, extensive peat bog areas; 4, localities of the buried humus beds; 5, patched peat bog areas; 6, peat bogs where the pollen analysis has been done.

A, Numakawa; B, Sarobetsu; C, Kotambetsu; D, Shibetsu; E, Bihoro; F, Shari; G, Horobetsu; H, Hakodate; K, Aomori; L, Nishitsugaru; M, Namioka; N, Hachinohe; O, Hachirôgata; P, Morioka; Q, Kitagami; R, Furukawa; S, Sendai; T, Yamagata; U, Imbanuma; V, Takaoka; W, Kanazawa; X, Osaka; Y, Kojima Bay; Z, Marugame; a, Saijō; b, Komatsujima; c, Kōchi; d, Izumo.

1, Kamegaoka; 2, Tsugaru Plain; 3, Mt. Hakkōda; 4, Mt. Hachimantai; 5, 5, Ōmagari; 6, Sendai Plain; 7, Ōyachi; 8, Akai; 9, Futanuma; 10, Niigata Plain; 11, Kinunuma; 12, peat bogs around L. Ozenuma; 13, Ozegahara; 14, Senjōgahara; 15, Kakumanbuchi; 16, Ominenuma; 17, Naeba; 18, Nozori; 19, Shiga; 20, Shirane; 21, Sugadaira; 22, Yashimagahara and Tateshina; 23, Karakemi; 24, Kamikōchi; 25, Mt. Ontake; 26, Uotsu; 27, Kanazawa; 28, Chōshi; 29, Kujūkuri Plain; 30, Kamo; 31, Kemigawa; 32, Nakagawa lowland; 33, Ichikawa; 34, Sanpōji; 35, Sengokubara; 36, Kanogawa plain; 37, Ukishimagahara; 38, Nōbi Plain; 39, Kyōto; 40, Daisen; 41, Yawata; 42, Kujū; 43, Kirishima; 44, Kimotsuki plain; 45, Yakushima.

of the regions having the heaviest precipitation in the world, and the annual precipitation of Japan reaches 1,000 to 4,000 mm except in the eastern part of Hokkaido, the basins in Central Honshū, the northern part of Honshū, part of Setouchi (the mediterranean sea region), where the annual precipitations are each less than 1,000 mm. Annual precipitation of the intensive peat forming areas in the world is generally less than 1,000 mm, and the regions having precipitation over 1,000 mm are only the western part of Norway, the western part of England and Ireland. It is well known that the peat bogs in these regions have the topography peculiar to the peat bogs developed under the extremely maritime climate. Consequently it is considered that character of the peat bogs in Japan may be similar to those in these regions.

Most of the peat bogs in Japan are situated in recent volcanic regions and the alluvial plains in Central Honshū and northward (Fig. 4). Such landforms as a dammed basin made by lavaflow or mudflow, a shallow depression of lavaflow or mudflow, a gentle slope of volcano composed of weathered volcanic ash, a spring site of the slope or foot of volcano and so on in recent volcanic regions are the places adequate to the formation of the peat bog (Fig. 5). Accordingly the volcanic ash layers are often intercalated in the peat deposit, and we can find even such a thin layer as it is difficult for us to find in other kinds of deposits. For this reason the tephrochronological method is more useful for the peat layer than for the other deposits, and plays an important part in the correlating of the peat deposit and the making-up of the chronology of the Holocene epoch.

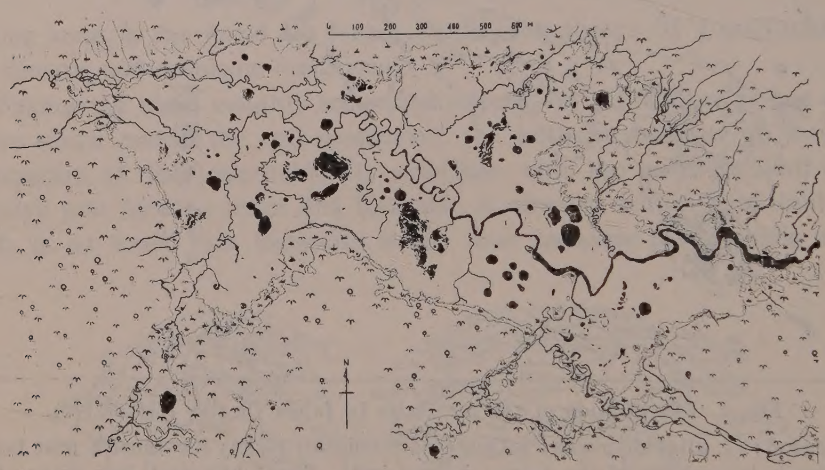

Fig. 5. Uryūnuma highmoor. This peat bog is situated on the lava-plateau, 800 m above sea level, one of the Shokambetsu volcanoes. Part without symbols: the area growing hydrophytes. Note the circle-shaped ponds.

While the *Sphagnum* peat bogs are formed in the mountainland from Hokkaido to Yakushima Is. south to Kyūshū, in the lowland their southern limit of the occurrence coincides approximately with the isotherm of 20°C of the

mean temperature of July.[2] Vegetations of the peat bogs mainly consist of *Sphagnum* sp. *Carex Middendorffii*, *Rhynchospora alba*, *Oxycoccus vulgaris*, and so on in the high moor; *Empetrum nigrum*, *Moliniopsis japonica*, *Scheuchzeria palustris*, *Picea jezoensis*, *Betula* sp., and so on in the transitive moor; *Phragmites communis*, *Carex* sp., *Zizania latifolia* and so on in the low moor. A forest moor occurs very rarely in Japan, except alder one.

In the lowlands of Japan most of the bogs have been developed from so-called backswamps formed in the interfluves or between a river channel and valley-side. Especially the peat bogs developed in the small valleys of the uplands have often the characteristic of the spring moor. Though most of the peat bogs in the mountainland belong to the type of *Verlandungsmoor* or *Versumpfungsmoor*, in such a large basin as Ozegahara moor the peat bog develops from the backswamp as the peat bogs in the lowlands. Judging by climatic and topographic conditions the types of the peat bogs in Japan belong to L. von POST's topogeneous and soligeneous moors. The thickness of the peat layer in Japan is 8 to 9 m in maximum value, 3 to 5 m in mean value, and both of them completely coincide with the values taken from here and there in the Northern hemisphere.[3]

Since the distribution area of the peat bogs in Japan is very small, it is yet very few who have interest in the peat or peat bog problems, except some special research fields. Therefore it has hardly been understood what the problem is and how important is the study of it. The reason that the author has taken up the peat bog as an object of study is due to the view-point that the peat layer plays an important part as a key in making clear the paleogeographical problems in the Holocene epoch.

The peat deposit exists not always in the Holocene formations, but also in the Pleistocene and the Tertiary formations. The peat layers of 2 to 3 m thick have been intercalated in the terrace deposits along the Sea of Japan in Hokkaido, and they have been referred to the Pleistocene epoch by pollen analytical method. While the total area of the peat bogs formed during the Holocene epoch in Hokkaido is about 190,000 ha, occupied as much as 38% of the whole alluvial plain of Hokkaido, the area of the old peat layers here is nearly negligible. Now, it can not be doubted that peat bog forming has been done all over the world during the Holocene epoch. However, it can not always be said that peat bog forming during the Pleistocene epoch was not so intensive as that during the Holocene epoch, though a distribution of the Pleistocene peat deposits is restricted. It may be considered that we cannot see the old

2) The southern limit of the high moor in the lowlands is Tanabu in Shimokita Peninsula, the north end of Honshū, so far as the author knows, and there occurs *Sphagnum* sp. *Carex Middendorffii* and *Myrica tomentosa* (MATSUI & OTAKE, 1957).

3) According to K. E. IVANOV (1957) the peat layers in the USSR are as follows: 25–30 cm in the Siberian arctic circle, 3-4 m in the northern part of the taiga zone, 8-9 m in maximum in the middle and southern part of the temperate forest zone, but decreasing again toward the south from this zone the thickness becomes 1-3 m. It is about 10 m in maximum in Finland after E. A. MALM (1912).

peat layers because they have been covered with the recent deposits or eroded after accumulation. Also, because of diagenesis a peat layer becomes thinner with age. Or under such a climatic condition as the tundra zone the peat layer is thin, although peat forming has gone on for a long time. For these reasons it is difficult to estimate the accumulation time range judging by its thickness only. But in spite of these uncertainties, it may fairly be said that the Holocene epoch is an intensive peat forming time.

The peat is an autochthonous deposit, and is very sensitive to changes of the endogenetic or exogenetic peat forming factors, for example, climate, topography or physical and chemical properties of water, but if these factors are unchangeable, the accumulation goes on regularly throughout the whole time of peat forming. Changing of pollen flora, intercalating of such inorganic deposits as volcanic ash, clay, and sand, changing of the decomposition grade showing in the peat layer are regarded as the faithful records of changes of the environment at that time.

We can make calculation of the absolute age of the peat forming time with the peat layer itself, because in general the accumulation of peat goes regularly on, and its mean rate of accumulation per year is nearly constant all over the world. Moreover, as the peat is the material fitted for C^{14} dating method, we can establish such a precise chronology for the Holocene epoch by this method as we can scarcely expect for the other geological ages. We can also recognize changes of the environment and make correlation of peat layer with others with pollen analysis, micro-fossil analysis, decomposition grade analysis, and so on. Moreover, it is possible to determine the relation between peat bog and other land forms by tephrochronological method. Reversely ages of volcanic ash layers may be determined by the growth of peat.

When we skillfully apply these characters of the peat deposit, we can logically understand the sequences of the changes of climate, forest vegetation and land forms, pre-historic events and their mutual relations.

2. Rate of the Accumulation of Peat.

The rate of the accumulation of peat depends on climate, topography of peat bog, peat forming plants, decomposition grade of peat and intensity of diagenesis, and is commonly very varied not only by location but also by horizon. The rate of accumulation of surface peat horizon can be determined by special characteristics of such hydrophytes as *Drosera rotundifolia*, *Oxalis acetosella*, and so on. This method also can be applied to the trees. The roots of the firs or spruces grow on the peat bog branch radially from their stumps, at the depth of about 2 cm, but such roots never branch from the same stumps after they have been covered by the peat. Consequently, we can estimate the rate of peat accumulation by measurement of the depth of the root branching part and by the number of the annual rings of the trees. The values of the rate of accumulation referred by K. BERTSCH range 7 to 24 mm/year and the average value of 136 localities in Fichtenwald is 21 mm/year. The European values referred by

URAGAMI are 20–25 mm/year similar BERTSCH's values. As summarized above, except the extreme ones, the rate of accumulation of surface peat layer may be considered 20 mm≧. L. HEIKURAINEN has made it clear that the rate of peat accumulation varies according to the gradient of the bog surface and the micro-relief of the peat bog in the Finnish eutrophic peat bogs. According to his investigation, its values at the slope of the gradient of 1/1,000 are 1.2–1.3 mm/year at the *Schlenke*, 4.8–4.9 mm/year at the flat part, and 5.0–8.8 mm/year at the *Bülte*; moreover its values become larger with the decrease of the gradient. The results which the other investigators have determined by the same method are ranged 2.2 to 33.5 mm/year. S. SCHNEIDER has also proved that the rate of accumulation depends on the kind of *Sphagnum* and its value ranges 7 to 70 mm/year. In Europe the mean rate of the accumulation of peat has been also calculated from the remains contained in the peat deposit. For example, in North Germany the rate of accumulation has been calculated at 0.5–1.2 mm/year by the roads, bridges, coins, weapons and so on, referred to the Roman period. Though the peat bog relics are very few in Japan, we have taken the value of the rate of accumulation of about 1 mm which has been calculated by the result of C^{14} dating (1122 ± 180 B.C.) for a piece of the canoe excavated from the base of the peat layer of 3.5 m in thickness at Kemigawa, near Tokyo; and at Ozegahara, one of the typical high moors, we have also obtained the value of 0.7–0.8 mm/year by the same method. In Japan such a calculation has been taken of the volcanic ash layers that the times of eruptions are clear. Some results obtained by this method are as follows:

Rate of Accumulation	Locality	Calculator
0.9–1.0 mm/year	low moors in Hokkaido	S. YAMADA
av. 1.4	floating *Sphagnum* bog at L. Yunoko, Nikkō	K. MIYAI
1–3	ordinary *Sphagnum* bog at L. Yunoko, Nikkō	K. MIYAI
av. 1	peat bogs situated in the central mountainland of Honshū	S. HORI
0.3–1.3	Ozegahara	the author

The author has calculated the rate of accumulation in each age of the Holocene epoch owing to the results of the pollen analysis in NEISTADT's treatise of 1957, *The Forest History and Paleogeography of the USSR in the Holocene Epoch.*

	Min.	Max.	Av.	
early Holocene (Hl_2) (7700–9800)	0.09 mm	1.91 mm	0.63 mm	(21 localities)
middle Holocene (Hl_3) (2500–7700)	0.12	0.67	0.32	(48 localities)
late Holocene (Hl_4) (0–2500)	0.20	2.00	0.99	(60 localities)
average of all the localities			0.65	

Here we should take notice of the fact that the value of the middle Holocene is remarkably small.

As summarized above, it can be considered that the mean rate of peat accumulation in Japan is 1.0 mm/year except that of the surface peat horizon, and in most cases more than this value. In the following discussion the author applies the value of 0.8–1.0 mm/year for dating, except the case when peat is rather decomposed.

3. Decomposition Grade of Peat and Its Significance.

Accumulation of the peat takes place only in the case when the amount of the plant production surpasses that of the decomposition by micro-organism. The more the plant production is reduced, or the activity of micro-organism is vigorous, the smaller the rate of accumulation becomes. We can point out the following cases as the causes of increase of the decomposition grade:

1) when the peat bog has grown to the limit.
2) when the peat contains minerals such as volcanic ash, clay and so on.
3) when the air easily penetrates into the surface horizon of the peat deposit, because of the lowering of the ground water level.

According to E. WICKMAN the maximum relative height of the high moor reached to an equilibrium state is proportional to the squares of both the annual precipitation and the radius of peat bog. That is to say, this relation shows the existence of the limit of the vertical growth of the peat bog even if both values are unchangeable. We can actually see such a phenomenon in the peat bogs everywhere. The nearer the growth of the peat bog gets to this limit, the slower its rate of growth becomes. Consequently the surface horizon of the fully grown high moor may be relatively decomposed.

As already mentioned, we can often see in our country such a phenomenon as well decomposed peat horizons containing volcanic ash, pumice, clay, and sand.

Deepening of river channel in the peat bog brings such a result as drainage by drains. Consequently the penetration of air into the peat becomes easier, and the activity of the aerobic bacteria becomes more vigorous; the decomposition grade increases. Accordingly a well decomposed peat horizon sometimes indicates an inconsiderable change of the ground water level due to the transforming of landforms.

Lowering of the ground water level in the peat bog also occurs when the climate becomes dry. It also means that the well decomposed peat horizons are regarded as the indicators of the climatic change. Since BLYTT and SERNANDER many investigators have taken up the study of the well decomposed horizon from such a point of view. BLYTT has investigated the stratigraphy of the layer of about 5 m in thickness in Norway, and clarified that the continental dry and maritime humid climates appeared alternately during the postglacial age. C. A. WEBER has pointed out that the Subboreal *Sphagnum* peat strongly decomposed in the maritime climate regions of North Europe. Having considered that such a horizon was formed as a result of the increase of aridity, he has called such a layer *Grenzhorizont*. However, it is doubtful whether the climate

of the Subboreal time was drier than that of the Atlantic time or not. E. GRANLUND has recognized five such layers in Sweden, and T. NILSSON nine in Norway. Granlund has explained the cause of the occurrence of these layers as follows: when the plant production is reduced because of deterioration of the climate, the accumulation of peat becomes slower, and consequently the decomposition grade increases. The main *Grenzhorizont* in Northwest Germany (referred to 500 B.C.) correlates GRANLUND's RYIII in Sweden. According to F. OVERBECK the *Grenzhorizont* in Northwest Germany is represented not only by one horizon, but is composed of each horizon referred to 100 B.C., 600 B.C. and 700 B.C.; and two layers correlated RYIII and RYIV in Sweden have been found in England and Wales. That is, the *Grenzhorizont* forming period is different with the locality. It has been already mentioned that according to M. I. NEISHTADT's data the rate of the accumulation of peat in the middle Holocene is the smallest NEISHTADT's Holocene epoch. Though it is not always clear whether this cause is on account of the decreasing of the plant production affected by the increasing of aridity, as Overbeck said, or not; at any rate, we can make a division of the epoch at least these 9800 years by the rate of accumulation or decomposition grade of peat in Northern Eurasia.

Because increasing of the decomposition grade of peat occurs in such various manners as above mentioned, we must carefully interpret the significance of the decomposition grade of peat.

Now we must notice another important fact that the decomposition grade depends on the peat forming plants. The decomposition grade commonly becomes larger with the age of the peat (S. ODÉN, 1922). On the other hand, ODÉN has pointed out that *Sumpfniedermoortorf* was more apt to be decomposed than *Vaginatum* and *Fuscum*-peat and *Sumpfniedermoortorf* as follows: Oxygen which dissolves in water penetrates from the surface of the bog to the rather deep part of the peat layer, because the permeabilities of *Vaginatum*- and *Fusscum*-peat are better than that of *Sumpfniedermoortorf*. The opinion as difference of the decomposition grade depends on peat forming plants has also been pointed out by M. SALMI. According to his analysis the decomposition grade ranges H1 to H3 in *Sphagnum*-peat, H4 to H6 in *Eriophorum-Sphagnum* peat, and H7 to H8 in *Carex-Sphagnum*, and *Sphagnum-Carex* peat. That is, with the reduction of the content of *Sphagnum* in peat, the decomposition grade becomes larger. Accord-ding to Waksman, 1 part of soluble nitrogen to 30–50 parts of cellulose are necessary when fungi and bacteria decompose the organic matter. The nitrogen content of *Sphagnum* peat is, however, rather small as compared with other sorts of peat. Consequently *Sphagnum* peat does not decompose so rapidiy as other sorts of peat.

Therefore we can not simply decide why the decomposition grade increased. Nevertheless, the author considers that the change of the decomposition grade in the peat profile corresponds successively to the changes of the environment. As mineral matter which is mixed with peat and affects the decomposition of peat can be distinguished from peat forming matter by the naked eye, microscope or simple mechanical analysis and so on, the varieties of peat forming

plants also can be determined by the naked eye or microscope; we can eliminate the effect of mixed matter and peat forming plants from the causes of decomposing. If the increase of the decomposition grade is caused by climatic change, the same phenomenon should also appear in other localities under the same climatic conditions. In this case, as the climate affects not only the water content in the peat bog but also the forests around the peat bog and changes their character, we can expect a certain relationship between the pollen flora and the decomposition grade of the peat. The increase of the decomposition grade due to the change of topography is local as compared with that of climate. When the well decomposed horizon is chronologically connected with the events in the development history of landform in the surrounding area, the cause of the decomposition must be sought for in the change of topography. Whether a peat bog has fully grown or not may be decided by ecological investigation and topographic survey.

Here the author determined the decomposition grade of peat by L. von POST's grip method or by KUDRYASHOV's washing-out method. According to the author's test the relation between both methods is shown in the following table:

DECOMPOSITION GRADE OF TEST SAMPLES BY VARIOUS METHODS

	Washing-out method			Grip method
test sample	by water	by KOH-solution	by KOH-solution after air dry	
A	64.7%	73.5%	79.4%	H 6-7
B	63.8	69.2	77.0	H 7
C	75.2	81.6	86.5	H 7
D	75.3	77.3	83.0	H 8
E	54.7	64.0	73.4	H 6
F	68.1	72.5	80.2	H 8

That is, H 6, H 7, and H 8 respectively correspond more than 50%, 60±5%, and 70±5%.

4. On the Lower Limit of the Holocene Epoch.

Is it really possible to decide the boundary between Holocene (Alluvial) and Pleistocene (Diluvial) epoch by the world-wide geological events? The time interval of Holocene epoch is merely a moment as compared with the older geologic ages. Therefore, the tempo of the earth's historic evolution is too slow to decide the lower limit of such a short temred epoch. Though the Quaternary period is also commonly characterized by glaciation and human activities, both of them have not always universality all over the world. At this stage it may be better that the lower limit of the Holocene epoch should be determined according to the stage of geological development of that area. Because of this point of view, we must avoid using the terms of the Holocene epoch without any limitation. The terms *glacial*, *interglacial*, and *postglacial* ages are not always adequate today as the problems of the Quaternary period are investigated in the non-glacial regions. From this view-point P. WOLDSTEDT has suggested using *Kaltzeit* for *Eiszeit*, and *Warmzeit* for *Interglazialzeit*. Fur-

thermore, it is a question whether today is really the postglacial age or not, or whether it is an interglacial age or not. WOLDTSEDT has regarded the present day as an interglacial age, and distinguished the Holocene epoch from the Pleistocene epoch as being an especially significant time. K. von BÜLOW, has asserted that the Holocene epoch should be called the postglacial age, not an interglacial one, because it was the time of human activities, though the present has the characteristics of an interglacial age. While WOLDSTEDT has considered the postglacial age as the time after the last glacial age, A. M. ZHIRMUNSKII and H. F. OSBORN have regarded it as part of the time when the ice sheets were retreating. ZHIRMUNSKII has used *the Holocene epoch* for the postglacial age, for the reason that the postglacial age is not only once, because a postglacial age generally follows after each glacial age; some regions are today under the glacial age conditions. M. MINATO has distinguished the Holocene epoch from the postglacial age, having considered the postglacial age as the stage of the last glacial age. Many investigators of the Quaternary period, however, have regarded the Holocene epoch as the postglacial age.

It is natural that the boundary between the Pleistocene epoch and the Holocene one is different according to the investigators, because the time when the earth became free from the ice sheets differed regionally. It is not so difficult to find the geologic events that are effective for the division of the Quaternary period in North Europe. Many European investigators of the Quaternary period have regarded the lower limit of the postglacial age as the time of 6,800 B.C. or about 8,000 B.C. The lower limit of 6,800 B.C. has been determined by G. de GEER. According to his determination, the postglacial age began at the time when the last ice sheet in North Europe retreated as far as Lake Ragunda in Central Sweden and separated into two parts. This limit, as J. K. CHARLESWORTH said, is not surely universal. But that is never determined voluntarily. According to F. KLUTE it was about 7,000 B.C. when the temperature of July was higher than any value during the Alleröd age regarded as the real beginning of the warm period. This time is characterized by the occurrence of the mixed oak forest, the predominance of the pine, and the retreat of the birch. M. SAURAMO has investigated the raised beaches formed during the late- and postglacial ages in the southeastern sector of Fennoscandia, and pointed out that the mode of the crustal movement after *Echineis* phase was different from that in and before the same phase. Namely, during the time 7,000 B.C. until 6,500 B.C. the mode of the crustal movement changed from a process of uplift without tilting to differential tilting. This turning point of the mode of the crustal movement just coincides with the beginning of de GEER's postglacial age. A. PENCK, E. BRÜCKNER, E. HAUG, A. M. ZHIRMUNSKII, M. SAURAMO, J. BÜDEL and others have had the same opinion concerning the lower limit of the postglacial age or the Holocene epoch, while, there are many investigators who have considered the lower limit of the Holocene epoch as 8,000 B.C. It is because the deposits during the Fini-glacial age have nearly preserved the characteristics of the glacial age. According to F. KLUTE the temperature curve rose suddenly after the second Salpausselkä stage. The

temperature during the period from that time to the present has never become so low as it was before. Consequently this lower limit is also one of the turning points in the climatic history; furthermore, it coincides with the boundary of the paleolithic and the neolithic times in Europe. D. A. Pravoslavlev, R. Grahmann, F. Firbas, C. Rathjens, J. K. Charlesworth, P. Woldstedt and others have supported this limit. The time antecedent to the postglacial age is the lateglacial age. C. Rathjens has considered the forming of the Pomeranian endmoraine as the beginning of the lateglacial age. A. Penck, E. Brückner, R. Sernander, E. Haug, H. F. Osborn, W. Soergel, A. P. Pavlov, A. M. Zhirmunskii, K. von Bülow, G. de Geer and others have also recognized the lateglacial age, but have included it either in the Holocene epoch or in the Pleistocene epoch. Among them R. Sernander, W. Soergel, A. P. Pavlov, K. von Bülow and others have included it in the Holocene epoch.

Notwithstanding that the boundary of the Holocene and the Pleistocene epochs in Japan in uncertain like that of the Pleistocene and Pliocene epoches, the former has not yet been discussed as the Plio-pleistocene boundary. Judging from Japanese geologists' description of the recent sediments most of the Japanese geologists have not regarded their Holocene epoch as de Geer's postglacial age. The upper part of the deposits consisting of the recent coastal plains is chiefly terrestrial, and generally the middle and lower part is marine, and in many cases they overlie unconformably on the Pleistocene formations. The Holocene formations in Japan consist of two such kinds of deposits. Y. Otsuka has divided the Holocene series into two, aI and aII. This is represented by every deposit forming the recent alluvial plain, and that by the shell bearing marine deposits of the *postglacial age*. In this case, the meaning of this *postglacial age* is not always clear, either. Today, as the climatic changes since the last glacial age is not yet fully made clear, it is not adequate to divide the time with a climatic change. M. I. Neishtadt having divided the Holocene epoch in the USSR has regarded the time when organic matters were first deposited in the lakes in the central part of the European Territory of the USSR as the lower limit of the Holocene epoch. Now the author attempts to regard the beginning of the formation of deposits, which continue until the recent ground surface near the shore line of the coastal plains, as the limit in Japan. In Japan after the forming of the last Pleistocene marine terrace surface a conspicuous upheaval took place with differential tilting, and the rather uniform subsidence followed it everywhere in Japan, and the alluvial plains were formed. Such uniform subsidence of the land or transgression of the sea is known everywhere, notwithstanding that the Japanese Islands are an active zone of the crustal movement. H. Iseki and S. Kaizuka have considered this transgression and the preceding regression were based on the change of sea level by the glacial eustasy. The world-wide event by which we can determine the boundary between the Holocene and the Pleistocene epochs may be nothing more than the change of sea level.

According to many investigators the maximum stage of the Würm glacial age is the Brandenburg or the Pomeranian stage. However, we cannot yet

find an agreement on the problem of how the temperature changed after the end of the Würm maximum age, except the time of 10,000 years in the past. Consequently the change of sea level in the first half of the deglaciation period is not yet clear. According to J. Büdel the annual mean temperature curve begins to rise gradually after the Brandenburg stage, and after the Alleröd time the curve comes slightly down again. After the younger Dryas time the curve begins to rise abruptly, however, it does not show a large fluctuation during the postglacial age. As rising of temperature causes an ice sheet to melt, it can surely be said that the rising of the sea level occurred after the Brandenburg stage. To estimate the tempo of the melting of an ice sheet we must observe the temperature during the summer half of a year, because the temperature of the summer period is more effective than that of the winter period for melting an ice sheet. From this view-point noting the curve of the mean temperature of July by E. Klute, his result coincides well with that of Büdel. Accordingly, we may infer that this rapid transgression based on the glacial eustasy occurred after the second Salpausselkä stage.

In this discussion the author treats the time from the closing of the Würm maximum age to the recent as the Holocene epoch. What are relatively well investigated among the deposits during the Holocene epoch are those referred to the latter half of this epoch. If we assume the end of the Würm maximum age as 20,000 B. C. or 18,000 B. C., it may be said that we have no knowledge of the marine Holocene deposits during about 10,000 years. The lower limit of the Holocene epoch should finally be determined when the nature of these unknown deposits would be made completely clear. T. Shikama has divided the Holocene series into two stages, the Numian and Yurakuchoan in ascending order. But the geological subdivision of the Holocene epoch is yet tentative in Japan and many investigators have applied the prehistoric divisions, that is, in ascending order, pre-Jōmon (Non-ceramic culture), Jōmon, Yayoi, Burial Mound and historic periods. Tbe Yayoi period is generally characterized by rice culture. The Jōmon period is commonly divided into five substages—the earliest, early, middle, late, and the latest. The nature of the Pre-Jōmon period is not yet clear. The author applies these prehistoric divisions in this discussion.

II. Geomorphic Development of Sarobetsu Lowland

1. Outline of the Region Investigated.

The Sarobetsu lowland is situated in the lower course region of the Teshio, Northwestern Hokkaido. Most of the lowland is occupied by peat bogs (Fig. 6). In the western part of the lowland, along the Sea of Japan, the sand dune zone of 3 to 4 km in width runs nearly in a straight line to the north-west-north. The lowland is bounded on the north, east and south by the Sōya hill which consists of the upper Tertiary formations with very weak folding. In the lowland there are two island-like uplands (Hōtoku upl. and Maruyama upl.) consisting of the same formations as the Sōya hill. The Sarobetsu lowland is regarded as an imperfect basin both geologically and topographically. The

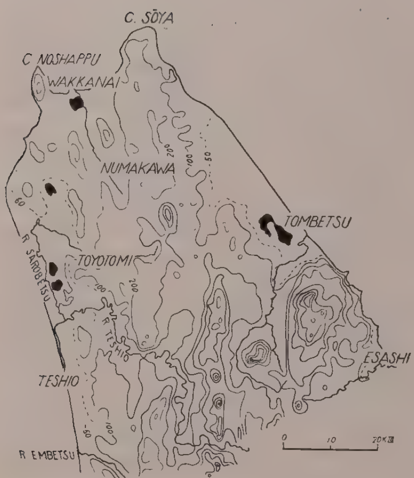

Fig. 6. Summit level of the surroundings of the Sarobetsu lowland. contour interval : 100 m.

elevations of two marine terraces along the coast of Northwestern Hokkaido, the author's C- and T-terraces, become lower just in the lowland (Fig. 7). This facts shows that the basin forming crustal movement yet takes place successively since the upper Tertiary. The Sarobetsu lowland is divided into the following four subdivisions: the sand dune ranges along the coast, the natural levees along the Sarobetsu, Teshio and so on, the peat bogs in interfluves or between rivers and hills, and Lakes Kabutonuma, Penke-to and Panke-to (Fig. 8).

The Sarobetsu peat bogs consist of 9,000 ha of a eutrophic peat bog, 3,900 ha of a mesotrophic one, and 1,700 ha of an origotrophic one, and they are one of the greatest peat bog areas in Japan (Fig. 9). The eutrophic peat bogs are chiefly situated in a margin of other peat bogs and covered with vegetation consisting of *Phragmites*, *Caramagrostis*, *Sasa* and *Alnus*. The mesotrophic peat bogs are usually accompanied by oligotrophic ones, but in some places from patches among other peat bogs. The oligotrophic peat bogs are chiefly found in the middle of the peat bog area. We can see *Carex Middendorffii*, *Eriophorum vaginatum*, *Sphagnum* sp., *Myrica gale* var *tomentosa*, *Ledum palustre*, *Oxycoccus vulgaris*, *Moliniopsis japonica*, *Carex* sp., *Sasa*, and so on in the meso- and oligotrophic peat bogs. Trees such as *Alnus*, *Fraxinus*, *Betula*, *Abies*, and so on grow in the bogs near the Sōya hill. Along the river, *Fraxinus*, *Salix*, and so on grow on the natural levee to form the gallery forest.

The elevation of the peat bog area reaches 7 m above sea level in Kamisarobetsu which extends between the Maruyama and the Hōtoku uplands, and is a well-developed oligotrophic peat bog (Fig. 8). The elevation of the central part of Kamisarobetsu is higher than one of the natural levees of the Sarobetsu, but we cannot find a clear marginal slope such as Ozegahara. According to H.

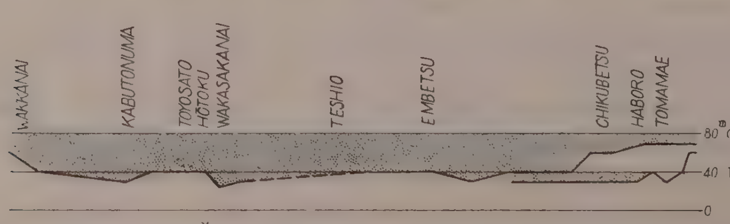

Fig. 7. Diagram showing the displacement of the raised shore lines along the coast of Teshio district.

Table 1. Division

Time scale (years): +1000, ±0, -1000, -2000, -3000, -4000, -5000, -6000, -7000, -8000, -9000, -10000, -11000, -12000, -13000, -14000

Scheme	Divisions (youngest to oldest)
A. PENCK & E. BRÜCKNER (1909)	Alluvium; Diluvium: Daun, Gschnitz, Bühl
R. SERNANDER (1910)	Holozän: Subatlantische, Subboreal, Atlantische, Boreal, Subarktische, Arktische; ?
E. HAUG (1911)	Holocène: Age du Fer, Age du Bronze, Époque Neolithique; Pleistocène: Würmien, Époque Paleolithique
H. F. OSBORN (1922)	Historic, Neolithic, Postglacial, Wisconsin ?
W. SOERGEL (1925)	Alluvium, Diluvium
A. P. PAVLOV (1925)	Holozän; Anthropogen: Neo-Würm
P. A. PRAVOSLAVLEV (1926)	Ober Quartär (Q_3): Neues Alluvium: Gegenwärtige, Subatlantische, Subboreal, Atlantische; Altes All: Boreale Übergangsklima; Mittel Quartär (Q_2): Ober-Diluvium: Spätglazial
K. von BÜLOW (1927)	Jung-Quartär: Jung-Alluvium, Alluvium, Postglazial: Jung-Post-glazial, Mittel-Post-glazial, Alt-Post-glazial; Alt-Quartär od. Diluvium: Spät-diluvial, Diluvial
R. GRAHMANN (1928)	Alluvium
A. M. ZHIRMUNSKII (1930)	Holozän(A3): Gegenwärtige, Subatlantische, Subboreal, Atlantische, Boreal; Pleistozän(A2): Neo-Würm: Fini-glazial, Goti-glazial, Dani-glazial
K. von BÜLOW (1931)	Jung-Quartär od. Alluvium in weiterem Sinn: Jungst-Alluvium od. Historische Zeit, Jung-Alluvium, Postglazial od. Alt-Alluvium: Spät (Alt-All.III), Mittel- (Alt-All.II), Früh- (Alt-All.I); Übergangs-zeit
G. de GEER	Postglacial (-6800); Finigl.; Gotiglacial; ?; Daniglacial
F. FIRBAS (1949)	Nacheiszeit: Jüngere Nachwärmezeit, Ältere Nachwärmezeit, Späte Wärmezeit, Mittelere Wärmezeit, Jüngerer Teil, Mittelere Wärmezeit, älterer Teil, Frühe Wärmezeit, Vorwärmezeit; Spätglazial: Jüngere Subarktische Z., Mittelere Subarktische Z., Ältere Subarktische Zeit
A. ANT… (195…)	Neo-thermal Epoch: Med… ther…, Al… ther…, Ana… ther…

s of the Holocene epoch.

Column	Divisions (top = youngest, to bottom = oldest)
…VS (cut off at left edge)	…al / …l / …l
J. BÜDEL (1953)	Holozan (Postglazial) / Würm-Kaltzeit: Spätglazial, Hochglaz.
M. SAURAMO (1954)	Postglacial / Fini-gl. / Goti-glacial
C. RATJENS (1954)	Postglazial / Spätglazial
J.K. CHARLESWORTH (1957)	Postglacial / Late-glacial
M.I. NEISHTADT (1957)	Holocene: Neo-holocene (Hl_4), Meso-holocene (Hl_3), Eo-holocene (Hl_2), Paleo-holocene (Hl_1)
P. WOLDSTEDT (1958)	Holozän, Postglazial, Nacheiszeit, Alluvium / Spät-Würm, Spätglazial / Mittel-Würm (Hochglazial)
P. WOLDSTEDT (1958): Studien der nord-europ. Vereis.	Eisteilung in Skandinavien / Salpausselkä III, II, I / Eisrand bei Leningrad / Langeland-vorstoss? / Pommerscher Vorstoss
P. WOLDSTEDT (1958): Abschnitte	Subatlantikum / Subboreal / Atlantikum / Boreal / -6800 / Präboreal / -8000 / Jüng. Dryasz. / -8700 / Allerödzeit / Altere Dryasz. / Bölling-Zeit / Alteste Dryas-Zeit
P. WOLDSTEDT (1958): Phasen der Ostsee	Mya-Meer / Limnaea-Meer / Litorina-Meer / Ancylus-See / -6500 / Echineis-u. Yoldia-Meer / Baltische Eistauseen / Ostsee eisbedeckt
P. WOLDSTEDT (1958): Phasen der Nordsee	Dunkirchener Transgression / Geringe Regression? / Flandr. Transgression, Corbula-Meer / Beginn d. Transgression d. Doggerbank / Nordsee teils eisbedeckt, teils Land
P. WOLDSTEDT (1958): Prähist. Eint.	Historische Zeit / Eisenzeit / Bronzezeit / Neolithikum / Mesolithikum / Jung Paläolithikum
H. ISEKI (1955?)	Alluvium
M. MINATO (1955)	Alluvium / Postglacial
Y. SAKAGUCHI (1960)	Holocene: Historic Age / Burial M. P. / Yayoi P. / Jōmon Period: Latest, Late, Middle, Early, Eariest / Holocene
Division of Prehistoric Age in Japan (T. ESAKA & S. KAIZUKA, 1959)	Historic Age / Burial M. P. / +300~+400 / Yayoi P. / -200~-300 / Jōmon Period: Latest, Late, Middle, Early, Earliest / Pre-Jomon Period, Period of Non-ceramic Culture
Dated sites (ESAKA & KAIZUKA, 1959)	Kemigawa Relics -1122±180 / Ubayama Shell Mound -2563±300 / Kamo Relics -3145±400 / Kizima Shell Mound -6443±350 / Natsushima Shell Mound -7491±400
Scale	+1000 / ±0 / -1000 / -2000 / -3000 / -4000 / -5000 / -6000 / -7000 / -8000 / -9000 / -10000 / -11000 / -12000 / -13000 / -14000

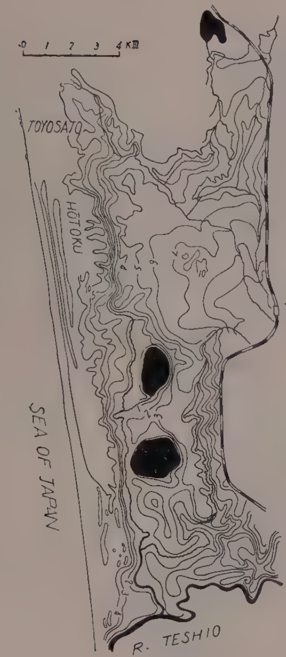

Fig. 8. Topographic map of the Sarobetsu lowland.

Fig. 9. Distribution of the peat bogs in the Sarobetsu lowland.
1, oligotrophic; 2, mesotrophic; 3, eutrophic.

Osvald such an oligotrophic peat bog appears in the region under the extreme maritime climate in Southern Sweden. Many *Rülle* are formed on the eu- and mesotrophic peat bogs surrounding the oligotrophic peat bogs. These *Rülle* may be formed by erosion of excess water which the peat layer cannot absorb and flows on the surface of the peat bog. From this interpretation we can understand the *Rülle* are easily formed on the surroundings of the oligotrophic peat bog, being dome-shaped, on which water continuously flows from the central part of the peat bog toward its margin.

2. Kamisarobetsu and Kabutonuma Areas.

The maximum thickness of the peat layer in Kamisarobetsu area is 8.75 m, and the base of the peat layer reaches 2 m below sea level. In most cases, however, the thickness does not exceed 5 m. The peat layer of more than 5 m in thickness in generally found in the oligotrophic peat bogs, and consists of slightly decomposed watery loose peat. The distribution of the remarkably watery peat layer can be traced as a narrow belt. The author considers this loose peat accumulated in an old river channel. The general sequences of the superficial deposits in both areas are as follows: clay—clayey peat—*Phragmites* • wood peat; or clay—clayey peat—*Moliniopsis* • *Phragmites* peat—*Moliniopsis* • *Eriophorum* peat; or *Moliniopsis* peat—*Moliniopsis* • *Sphagnum* peat—*Middendorffii* • *Sphagnum* peat—*Sphagnum* peat in ascending order. In Kabutonuma area an

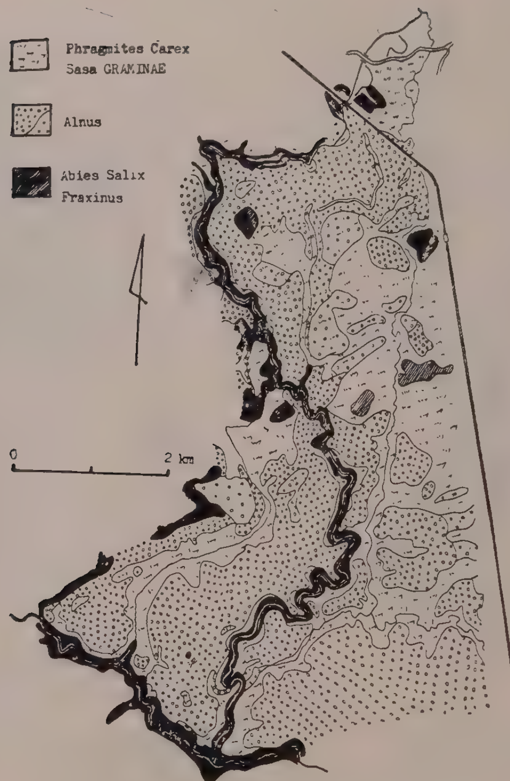

Fig. 10. Vegetation of Kabutonuma area.

alder forest is found as large as 2/3 of the whole area (Fig. 10). In the other part *Phragmites, Sasa, Carex, Moliniopsis, Caramagrostis,* and so on are growing. The places growing *Sphagnum* are considerably resticted. Two old channels are seen in alder forest. One of them is clearly traced and the gallery forest is formed along the old channel near the junction point with the Sarobetsu. As above mentioned, the vegetation of Kabutonuma area chiefly consists of the eutrophic hydrophytes. A vegetation pattern of this area is considerably more complicated than other part of the Sarobetsu peat bogs. This feature shows that conditions controlling the behavior of water and nutriment for plants are complicated. As the vegetation is strongly affected by the present geographical and pedological conditions, it is more or less possible to recognize synthetically the characteristics of the area in question by the observation of the vegetation. We can say that places growing *Phragmites, Caramagrostis,* and *Alnus* are most strongly affected or have been affected by flood. Places intensively growing *Fraxinus* and *Salix* along a river or the foot of a hill are also rich in mineral matter. From this point of view it would be possible to say Kabutonuma area was, as a whole, affected or have been affected by flood.

Fig. 11 shows the geological sections of Kabutonuma and Kamisarobetsu areas. We can see some volcanic ash layers in all sections of A, B and C. It would seem to be most fitting to say that these volcanic ashes are from the

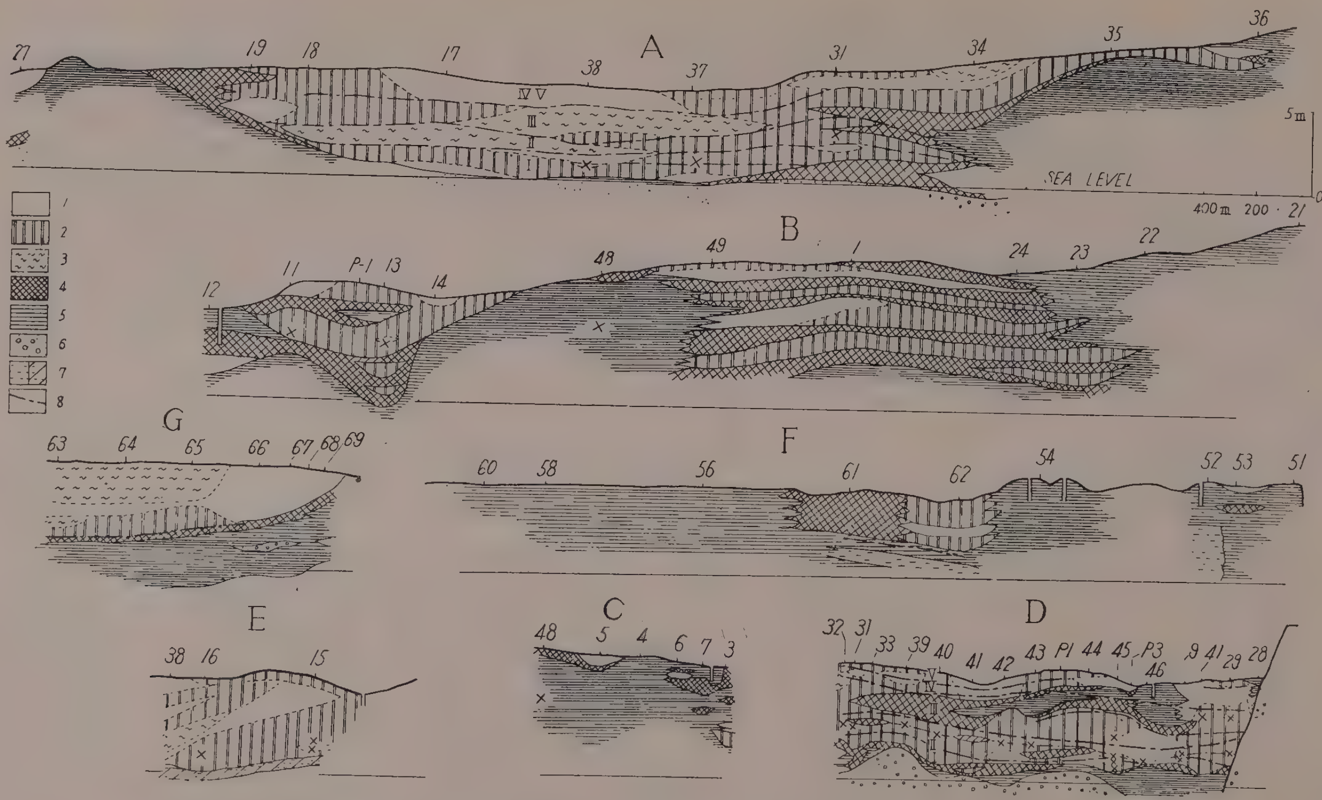

Fig. 11. Geological sections of Kabutonuma and Kamisarobetsu areas.
The locality of the sections is shown in Fig. 12.
1, peat of decomposition grade of H5≧; 2, peat of d. g. of H5<; 3, loose or watery peat; 4, clayey peat; 5, clay and organic clay; 6, sand and gravel; 7, silt (left) and organic silt (right); 8, isochronous line of the accumulation of peat; ×, volcanic ash.

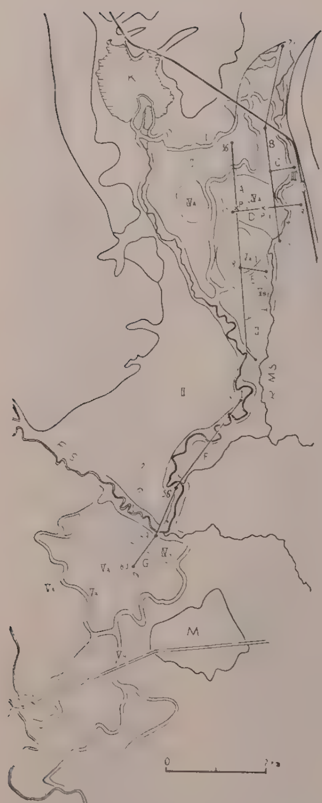

Fig. 12. Division of the superficial geology of Kamisarobetsu and Kabutonuma areas.

×, pits; A–G, localities of the sections illustrated in Fig. 11; K, Lake Kabutonuma; R. MS, River Mosarobetsu; R. S, River Sarobetsu; M, Maruyama; I, II, III, IVA, IVB, VA and VB, For explanation see text.

young volcano Rishiri situated in the sea of 35 km far from the Sarobetsu coast. Kabutonuma and the main part of Kamisarobetsu areas are divided into five parts by features of the superficial deposits as follows (Fig. 12):

I. Sarobetsu clay accumulated subdivision; the clay is homogeneous and sticky. Peat does not exist. The groundwater level is low. This part is the driest in these areas. *Salix* and *Fraxinus* chiefly grow here.

II. Clay and peat alternatively accumulated subdivision: Lithological facies are most complicated. The groundwater level is high. Alder grows vigorously.

III. Mosarobetsu clay accumulated subdivision: Here the clay of several metres in thickness is lying on the peat layer. The peat is considerably compact due to the clay load. The groundwater level is low. Stunted willow and *Phragmites* grow here.

IV–A. Peat accumulated subdivision A: The peat layer is divided into an upper and a lower part by clayey peat or an organic clay layer. The ground water level is high. *Sasa* and *Caramagrostis* chiefly grow here.

IV–B. Peat accumulated subdivision B; Continuous thick peat layer. The groundwater is high. *Moliniopsis*, *Carex*, *Saa* and *Osmunda* grow here.

V–A. Watery loose peat accumulated subdivision A.

V–B. Watery loose peat accumulated subdivision B: This part is the loosest in those areas. The initial land form before the accumulation of the peat may be a river channel.

3. Settling of River Courses in Peat Bogs.

We can find two different relationships between peat deposits and fluvial deposits in the above-shown geological sections. One of them is seen in the sections through the Sarobetsu or its old courses, the other though the Mosarobetsu. As shown in the A, B and F sections of Fig. 11 the deposits of the

Sarobetsu or its old courses are restricted to a certain limit. At the left bank of the Sarobetsu near the locality Ht the superficial fluvial deposits do not reach more than 70 m from the bank. According to the results of the boring on the natural levee near this point, peat does not exist through the whole core of 30 m in length. Though it is difficult to decide whether the accumulation of the peat has never taken place at this point, or the peat layer has been eroded away, this fact shows this place was under inadequate conditions for the accumulation of the peat. From this fact and behavior of the superficial deposits, it is considered that the peat bogs and the natural levees have each kept its own territory. Judging by the existence of the clayey peat it is recognized that rivers can invade more easily peat bogs, but commonly the invasion of rivers is not very strong, as rivers destory peat bogs and change them into another type of swamp. The author wishes to call this phenomenon *the settling of the river course in the peat bog*. The rivers in the lowlands of Hokkaido are remarkably meandering. At least in Hokkaido, the shifting of the river channel is restricted only in a meander belt, and the meander belt itself seldom shifts. *The river course* used here does not mean the present river channel, but such a meander belt. The same phenomenon has also been found in the Ishikari and Kushiro plains and Ozegahara basin. We can recognize from descriptions of K. von Bülow, H. Godwin, J. N. Jennings, V. Auer, and others that similar phenomenon also exists in Europe, though it was not expressed as *the settling of the river course*.

When backswamps are formed in the delta, *Phragmites* begin to grow along the margins of swamps. Among the conditions for the growth of *Phragmites* it is important that the water level of the growing area is relativel stable. According to E. Baumann a long-termed flood often destroys *Phragmites* thickets, whereas a contemporary lowering of the water level does not affect very strongly to the growth of *Phragmites*. The depth of the outer zone of *Phragmites* growing area in the lakes of Switzerland is 55 to 195 cm; the average, 120 cm. Accordingly, the formation of *Phragmites* thickets does not occur anywhere and anytime, but only when all the necessary conditions are filled. If such conditions are completely filled and *Phragmites* begin to grow and form thickets, mud is transported by flood in summer deposits directly along both sides of the river channel, because dispersal of mud is protected by *Phragmites* thickets. As a flood rarely takes place in winter and in many cases the river is frozen, the deposition of mud along the river is out of the question.

The Sarobetsu lowland is covered with floodwater for about two weeks in spring every year. According to the observation at the Sarobetsu the amount of matter transported by the floods in spring is very little. Consequently the the growth of the natural levee is chiefly caused by the flood in summer. The river course after the formation of *Phragmites* thickets settles in this way. However, if a river bed becomes shallower, or a floodwater level becomes higher, the river course could easily shift and incise in a peat bog such as the Mosarobetsu. If a river bed is deepend because of the upheaval of the land or regression of the sea, the settling of the river course may probably be more strengthened.

4. Investigation of the Boring Cores.

Boring survey has been made at seven localities in the lowland by the Hokkaido Development Bureau (Fig. 13). Characteristics of the deposits of four localities from No. 1 to No. 4 are as follows:

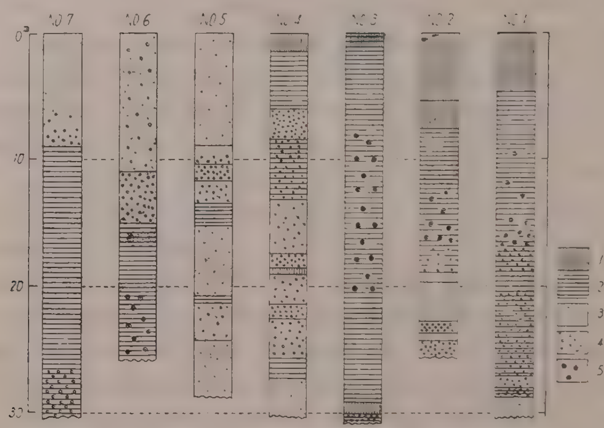

Fig. 13. Columnar sections of Kamisarobetsu area.
1, peat; 2, clay and silt; 3, sand; 4, gravel; 5, shells.

1) There exists *Corbicula* bearing silty clay layer. Its thickness is 26 m at the locality No. 3. The *Corbicula* fossils are abundant in the middle and upper parts, but not in the lower part of this layer.

2) There are peaty clay layers and black-gray sand and gravel layers. The kinds of gravel taken from all the boring cores are nearly invariable and consist chiefly of slate, sandstone, and chert. Siltstone or sandstone seen at the localities No. 4, 6 and 7 is correlated with the upper Tertiary (the Yūchi formation) composing the hill around the lowland judging by grainsize or hardness of the rock. The sand and gravel bed overlying the siltstone is regarded as the Sarobetsu formation which consists of unconsolidated sand and gravel and which unconformably covers the Yūchi formation, or its redeposited matter, perhaps terrace or talus deposits. The *Corbicula* fossils bearing silty clay may be referred to the Holocene series. A peaty clay layer of 90 cm in thickness lies at the base of the Holocene deposits, 26 m below sea level at the locality No. 3. This layer is a terrestical deposit before the accumulation of the Holocene deposits. There is also a peaty clay layer at 13.5 m below sea level at the locality No. 4.

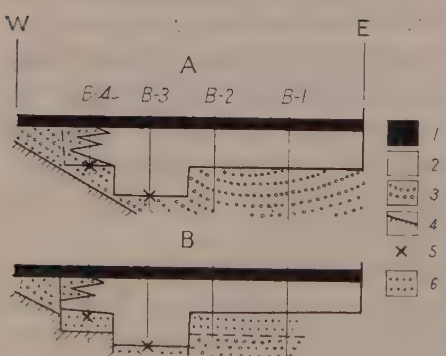

Fig. 14. Diagrams illustrating two views on the underground structure of Kamisarobetsu area.

1, peat; 2, clay and silt; 3, Sarobetsu formation and its redeposited sand and gravel; 4, Yūchi formation; 5, buried peat bed; 6, terrace deposit.

This layer is intercalated in the sand and gravel layers. There are two different ideas concerning the subsurface structure of the lowland as shown in Fig. 14. The author infers that the section B is appropriate judging from the land forms of the area surrounding the lowland.

5. Development of the Sand Dune Zone and Change of the Sea Level.

i. General features of the sand dune zone.

The sand dune zone lies in the north-west-north direction along the coast, the largest one in Hokkaido. The land-side of the zone is generally higher than the sea-side, and the northern part of the zone is higher than the southern one. The maximum height of the zone is about 20 m above sea level. The zone is divided into three ranges according to their forms. The range I lying on the eastside of a line through the western margin of the Hōtoku upland is composed of the parabola or horseshoe-shaped sand dunes which direct their convex front to the east or the east-north-east (Fig. 15). The sand dunes of the range I are considered to have been formed on the sandy hook spit. The surface of the sand dunes at the northern and southern parts of this range is coverd with brown loamy soil of more or less 40 cm in thickness. The sand dunes of the range II are arranged in line and divided into two subranges, IIA of the eastern-side and IIB of the western-side. The dunes of the subrange IIA are horseshoe-shaped such as those of the range I, and among the dunes there lie many bogs and ponds. The subrange IIB is 10 to 15 m above sea level in height, and only one line at Wakasakanai, but branches off into several lines at the northern and southern parts. The subrange IIB is easily distinguished from the IIA one, because the former is a continuous horseback-shaped dune. The range III is composed of the beach ridges more or less 5 m in height. A rather large peat bog is in the *low* between the innermost ridge of the range III and the IIB one. The range III becomes higher to the north, and at last

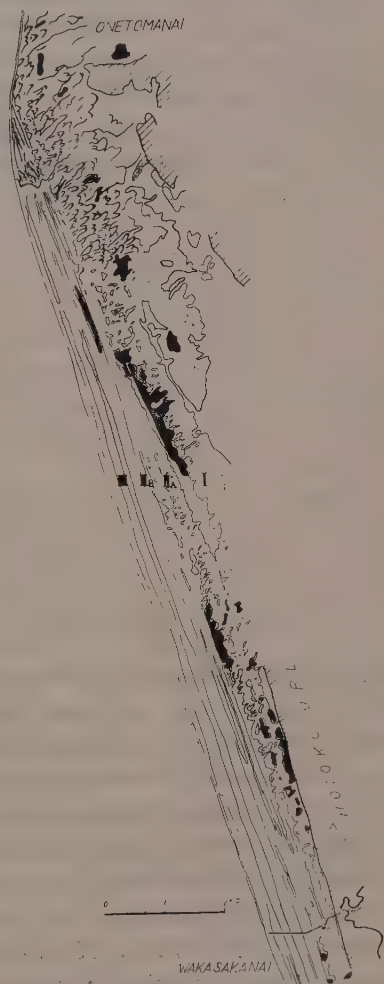

Fig. 15. Northern part of the sand dune zone of Sarobetsu.
black part, ponds; u-shaped symbols, crest lines of the horseshoe- or parabola-shaped dunes.

joins with the subrange IIB near the north end of this zone. Near the north end of the sand dune zone its direction changes to the northeast-north, and then to the northeast once more. The zone ends at each breaking point as if it were obliquely cut with a knife. On the ranges I and IIA *Abies* forest is formed, but the northern and southern parts of the range I are covered with *Sasa* and dwarf oak trees. The sand of the zone being fixed is entirely due to the vegetation cover. The vegetation of the range IIA is predominantly *Abies*, whereas that of the range II is *Quercus*. Therefore, the difference between the range IIA and the IIB one appears not only in their forms, but also in their vegetation. The vegetation of the range III consists of herbs only.

ii. Inner structure of the sand dune zone.

The range III is composed of beach ridges and is divided into four groups, IIIA, IIIB, IIIC and IIID from the land-side. The IIID is the highest, namely, 6.5 m above sea level, and the IIIB the lowest. Bog iron ores formed at the IIIA and IIIB, especially the thickness of the ore of the subrange IIIA reaches 140 cm (Fig. 16). The bog water is rich in iron; therefore, the bottoms of the

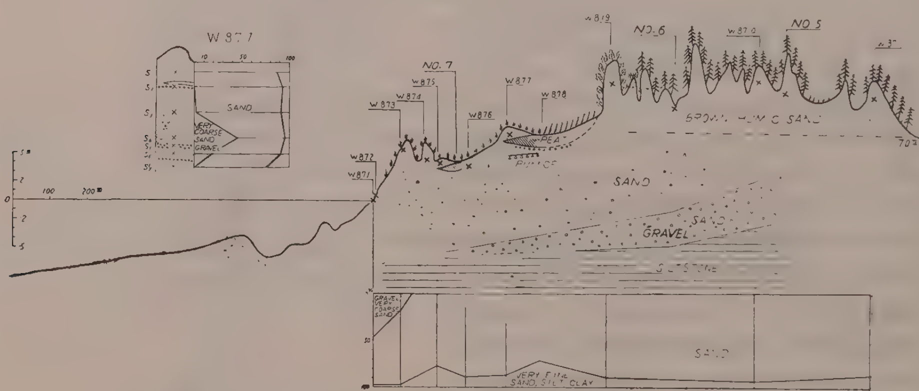

Fig. 16. E–W section of the sand dune zone at Wakasakanai.

ditches across the range III take on a red colour. We can find two pumice layers unders the one. The maximum grainsize of pumice is nearly as large as a fist. The pumice grains are well rounded, and are only in the *low* between the beach ridges. The sand bed intercalating these pmice layers is a beach deposit judging from its lithological characteristics. From these facts we can say as follows: these pumice grains transported by the long-shore drifting were thrown up on the beach by waves at that time. Or, when the ridges of the IIIC and IIID had been formed below the sea, these pumice grains were gathered by the movement of the water. If two pumice layers here are primary deposits, not secondary ones, the volcanic activities related with these pumice layers may have occurred in the period when the ridges of the range III were being formed below the sea, and when sand was vigorously accumulating on the subrange IIB. As the elevation of the pumice layers is 5 to 5.5 m above sea level, the sea level at that time should have been slightly higher than these values.

From the result of the mechanical analysis of the samples from the boring locality No. 5 situated in the subrange IIA at Wakasakanai, we can find a lithological boundary at the depth of 8 m. In the lower part of this boundary coarse sand and gravel predominate, whereas the upper part consists of nearly homogeneous fine and medium sand. As the upper part of 5 m in thickness of this homogeneous sand layer assumes a slightly brown colour because of iron oxide and humus, it is cleary distinguished from the lower part of this layer. It is clear that the upper part of this sand layer is terrestrial deposit. The elevation of this boundary is 6.5 m above sea level.

iii. Changes of the sea level.

The base of the sand dunes of the subrange IIA is beaca ridges such as the range III. Many investigators have studies the ridges or balls developing on the shallow sea bottom of the breaker zone. The author does not intend to explain here all these results. He intends only to discuss some results directly related to the changing of the sea level in such studies.

According to O. Evans, E. N. Egorov and others, if the forming conditions are the same, the position and size of the ridges are unchangeable; but if the sea level becomes lower, the ridges gradually shift to the land. Contrary to this opinion, W. Hartnack and V. P. Zenkovich have asserted the ridges shift to the land during the forming process, though the sea level is unchanging. Apart from the question of which theory is right, it is possible to say that in either case the top of the ridge situated in the most inner part roughly shows the sea level at that time directly before regression. Accordingly we can get the elevation of the sea level at that time by reducing the thickness of dune sand from the elevation of the dune ridge.

As the amount of 6.5 m taken by the boring data is regarded as the elevation of the ridge or trough, the maximum sea level of the transgression in this area is about 6.5 m above sea level. This value nearly coincides with the sea level estimated by the elevation of the pumice layers at the range III. From these results the change of the sea level during the forming period of the sand dunes of the ranges I and II was very little so far as the author saw at the sand dune zone.

The base of the peat layer lies near the sea level even at Kabutonuma area, the innermost part of the lowland. As the accumulation of peat begins at the time when *Phragmites* forms a thicket, it is necessary for the depth of water to be less than 1 m. As the maximum sea level of the transgression is 6.5 m above sea level at the sand dune zone, at that time the growth of *Phragmites* was impossible or very difficult, therefore there is no accumulation of the peat. The accumulation of peat should begin for the first time in the forming period of ths range III, when the position of the shore line was relatively near the present one. The time, however, elapsed since the sea retreated from the front of the subrange IIB was estimated to be 1,400 or 1,800 years, judging by the peat layer of 1.4 m in thickness lying between the subrange IIB and the range III. It is impossible to correlate this peat layer with the peat of 5 to 8 m in thick-

ness at Kabutonuma area. To explain this state without possibility of contradiction we must assume that a differential crustal movement has lately occurred between the peat bog area and the sand dune zone. As the value of the elevation of the raised beach situated in Embetsu, south of the Sarobetsu lowland, is nearly the same as the one taken at Sarobetsu, it seems that it is difficult to say the area of the Sarobetsu sand dune zone has especially made an upheaval. If the sand dune zone had made an upheaval, the subsidence of the Sarobetsu peat bog area would have been much stronger.

The regression occurred after the transgression reached the maximum level. We have not yet a sufficient answer for the problem of whether the time when the sea level was lower than the present one existed after the begining of the regression or not. But the author has got the very suggestive result in the Embetsu coastal plain situated 40 km south of the Sarobetsu lowland. At the locality E-912, north of Embetsu Town, the western part of the peat bog formed in the interfluve between the Uttsu and the Embetsu rivulet was eroded by waves, and the peat crops out along the coast (Fig. 17). It seems that a sand dune range formerly existed in front of the peat bog. If the inner range of the sand dune zone of the Sarobetsu lowland had extended as far as this in the same direction, it should be considered that the present shore line here has retreated about 500 m from the inner side of the sand dune zone that period. The retreat of the shore line does not always need the rising of the sea level. But it may also be explained that after the sea level fell, passing the present level and transgression took place again, the coast has been eroded. Even if this theory were right, the amount of the falling of the sea level would be unknown.

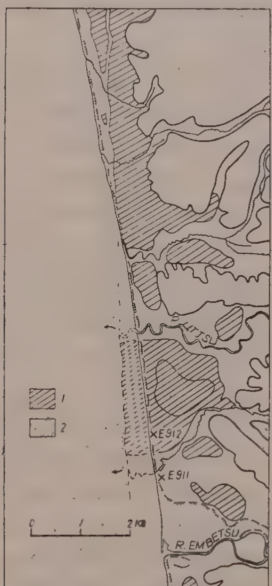

Fig. 17. Map showing change of the shore line of the Embetsu coastal plain. 1, peat bogs; 2, sand dune zone.

iv. Development of the sand dune zone.

In the Hōtoku upland (an elevation of 50 m above sea level) consisting of the sand and gravel beds of the Sarobetsu formation the erosion cliff running lineally north-west-north is situated in the west of the highest point of this upland facing the sand dune subrange IIA, while a terrace of an elevation of 20 to 40 m above sea level is formed in the eastern slope. When the erosion by waves and long-shore drifting took place at the western part of the former Hōtoku upland, at the northern part of this upland a large hooked spit was built with sand transported from the front of the upland at the same time. The formation of the spit took place during the transgression. The sea reached the maximum level, and kept nearly the same level for a considerably long time; and at the final stage of this period the shore line was situated in the front of the subrange IIP

After that the sea level fell repidly, and the sand dunes of the range III were formed. The sand dunes of the range II were formed during the settling period of fhe sea level. During this period the older sand dunes were transformed into a longitudinal type by wind erosion. One cause of the dune form of the IIA and IIB being different in spite of the movements of the sea level having taken place successively, is explained as follows: At first the supply of sand to the dune grows weak because of the retreat of the shore line. When a new sand dune ridge is born in front of the older one, it is difficult for sand transported by wind from the beach to reach the old dunes, because that sand was used in forming the new dune. Consequently the old dunes are eroded.

When the shore line retreated from the front of the subrange IIB, both surfaces of the ranges I and II were covered with vegetation. The sand dunes of the range III are good deal smaller than those of the ranges I and II. The cause may be that the age of the dunes is relatively young, and that the supply of sand from the beach was not sufficient because the distance from the beach rapidly incraesed due to the rapid falling of the sea level.

The author, however, considers the remarkable differences of scale, form and vegetation between the ranges I or II and the range III are caused not only by the changes of the sea level, but also by the climatic changes. Consequently the wind erosion during the forming periods of the ranges I and II was more vigorous than that of the range III during the forming period. Among the sand dune ridges of the range III the dunes of the ridge IIID are well developed and in the south this dune ridge is eroded by wind. From this fact the present seems to be a wind erosion period.

6. Earth History of the Sarobetsu Lowland.

i. Period of the Sarobetsu Sea.

According to the results of the pollen analysis of the peaty clay from the boring locality No. 3 the climate of that time was yet cold. It would be possible to say this peaty clay is the so-called basal peat which was formed by the rising of the ground water level accompanied by the transgression. During the transgression the basal peaty clay layer was covered with the *Corbicula japonica* bearing silty clay. The total rise of the sea level was $26.0+6.5+\alpha=32.5\,\mathrm{m}+\alpha$ judging by the depth of the basal peaty clay layer. The clorinity of the water which is necessary for living of *Corbicula japonica* is commonly less than 10‰. In order that this condition is completely satisfied in the Sarobetsu lowland, a barrier preventing the invasion of sea water must exist in the western part of the lowland. The base of the sand dune zone played such a part. The author gives the name of *the Sarobetsu Sea* to the sea which had extended from this barrier to the Sōya hill. During the early stage the Sarobetsu Sea was connected with the Sea of Japan at the north and south ends of the barrier (Fig. 18, I).

Fig. 18. Three stages in the development of the Sarobetsu lowland. I, period of the Sarobetsu Sea; II, period of the Sarobetsu Lagoon; III, Sarobetsu peat forming period.

ii. Period of the Sarobetsu Lagoon.

Soon after that, the north inlet of the Sarobetsu Sea was closed by a sand spit. This brackish water area is called *the Sarobetsu Lagoon.* That the shells of *Corbicula* are abundant in the middle and upper parts but absent in the lower part of the silty clay, is explained incontrovertibly by this change of landform. After the sea reached the maximum level, its level was kept in nearly the same position for a long time. During this period along the coast the ranges I and II were formed, and the older sand dunes were eroded.

Around the lagoon deltas were formed and the lagoon gradually became shallower due to the deposition. Seeing the eastern part of the section D of Kabutonuma area, *Trapa*'s fruits have been found in the organic clay lying under the base of the peat layer. We can find that a shallow pond of fresh water existed here before the beginning of the accumulation of peat. The peat bogs occurred from such ponds or interfluves. It has been pointed out that the accumulation of peat occurred almost simultaneously everywhere in the backswamps. According to the results of the pollen analysis of the samples, from Kabutonuma and Kamisarobetsu areas the formation of the peat bogs are considered to have begun 5,000 or 6,000 years ago. In this period wind erosion was vigorous. At that time such a big flood as prevented the growth of *Phragmites* did not occur, because the accumulation of peat presupposed the formation of *Phragmites* thickets and the settling of the river course. As it is necessary for the accumulation of peat that a big flood should not have occurred, it would seem the most fitting to consider that this time was drier than the foregoing one because of the decrease of the precipitation. The shore line at the last stage of this period would be situated in front of the subrange IIB (Fig. 18, II).

iii. Sarobetsu peat bog forming period.

Soon after the period mentioned above the sea level fell rapidly. The climate became humid. The sand dunes were covered with vegetation. The shifting of sand ceased. The partly-decomposed peat accumulated in the bogs. Perhaps the production of plants might increase compared with the foregoing dry period. Afterwards, however, the climate became drier again. Along the coast the sand dunes of the range III began to be formed. The Sarobetsu lagoon was filled. The peat covered the whole area of the newly born land. In Toyosato area open water existed for a long time, but finally this area was also covered with peat. *Corbicula japonica* bearing silt was formed under the peat layer of 1 m in thickness.

The springs are situated at the foot of the hill around Kabutonuma area. According to the results of the pollen analysis each synchronous surface of the peat deposit does not converge at the margin of the peat bog in Kabutonuma area. This fact shows that the peat bog extends over the slope of the hill, and the springs are closely related to the growth of the peat bog.

The sea level would have been somewhat lower than the present one for a certain period. A transgression would have occurred again. During this transgression the beach would have been slightly eroded (Fig. 18, III).

III. Geomorphic Development of Kushiro Peat Bogs

1. Outline of the Region Investigated.

Kushiro plain is situated in the southeastern part of Hokkaido, one of the greatest peat bog areas in Japan (Fig. 19). The total area of these peat bogs is about 25,000 ha. In the total area the eutrophic peat bog is 24,600 ha broad. The peat bogs are formed in interfluves. There is a relatively large oligotrophic peat bog covered with vegetation consisting of *Sphagnum*, *Eriophorum vaginatum* and so on in the northern part of the plain. The vegetation of the eutrophic peat bog chiefly consists of *Phragmites* and *Carex* sp. Trees such as *Alnus*, *Fraxinus* and so on grow principally in the peat bogs near the upland or the natural levees. There are countless rivulets in the bogs. We can see the water surfaces of some of them, but others are concealed by *Phragmites* thickets or completely covered with peat mat.

According to the study of aerial photographs, there is a topography similar to the lobate delta in the northeastern part of this plain. The elevation of this plain is 10 to 20 m above sea level at the highest part, and less than 2 m above sea level in the lowest part of this plain. Otanoshike-Tottori area is relatively high. This area may be the old delta of the Akan-Ninishibetsu. The Ninishibetsu was the former main course of the River Akan, and has a well developed natural levee. Along the coast from Otanoshike to Kushiro there lie eight beach ridges with an elevation of more or less 5 m above sea level. These ridges are covered with eolian sand, and the elevation of their top reaches 10 m above sea level. The dune zone makes an elevated zone of

3 km wide adjoining the natural levee of the Ninishibetsu. It is remarkable that the elevation of the inner part of this plain is lower than that of the coastal part.

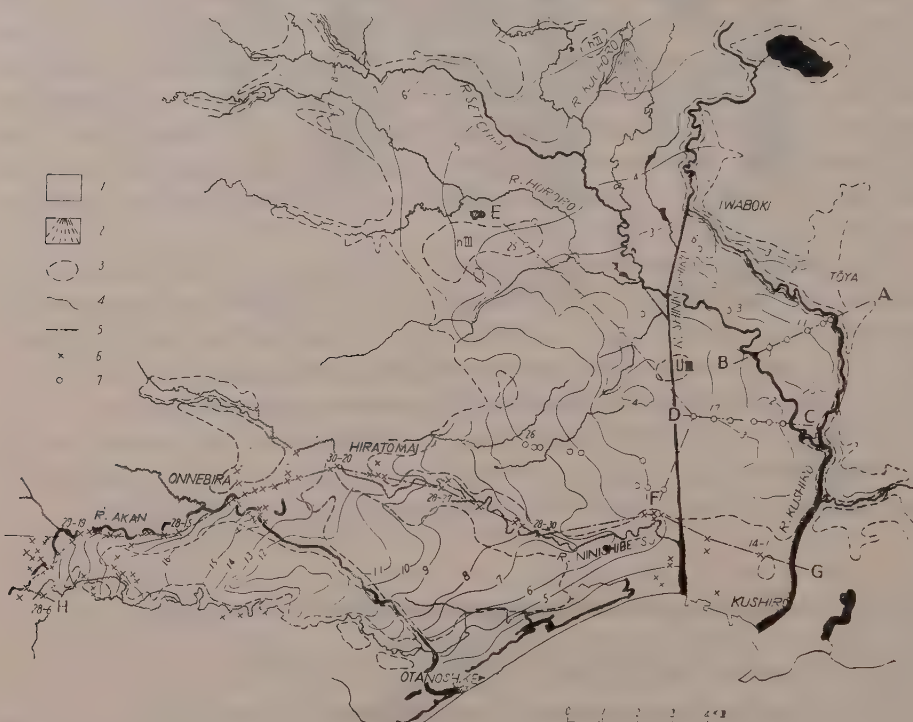

Fig. 19. Geomorphic map of the Kushiro plain.

1, natural levees and sand dune zone. 2, lobate-deltaic micro-relief.
3, boundary of the peat bogs. 4, contour line.
5, locality of the sections. 6, boring localities.
7, hand-boring localities.

2. Geology of the Superficial Deposits.

The sequence of the peat layers is generally simple (Fig. 20). The maximum thickness of the peat layers is only 4.4 m. The deposited area of the thick peat is local, and in most cases the thickness is at most 3 m more or less. The base of the peat layer consists of sand, sand with gravel, or clay everywhere. We can always see shell fragments in the basal deposits. Such fossils appear as far down as 18 m at the locality No. 14-1 situated between the Shinkushiro and the Kushiro. They have also been found under the peat layer at Higashikushiro. The decomposition grade of peat is H3 to H7, and generally becomes higher toward the base. Also the watery peat generally predominates in this plain. In a lower part of the peat layer lying near the locality No. 26, a great many timbers are observed along the wall of the canal. The peat deposit here is allochthonous. Several volcanic ash layers are intercalated in the peat layer. The sections through the peat bog are shown in Fig. 21. The

elevation of the base reaches 0.5 to 1 m below sea level at the section of a-b. From these sections it is clear that the Kushiro peat bogs have been formed at the interfluves and the settling of the river course is also recognized. According to the section of e-f, the base of the peat bog inclines to the north, opposite to a general trend of the surface of the plain. If a precise topographic survey is carried out, the inclination of the base may become larger.

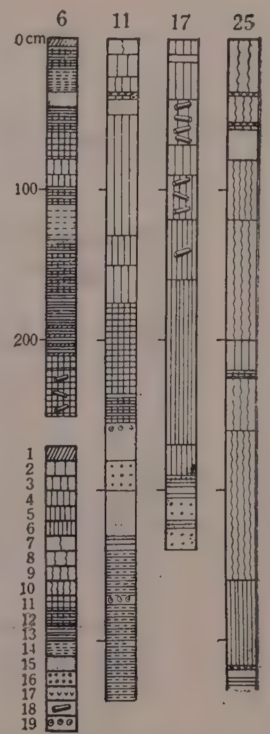

Fig. 20. Typical columnar sections of the Kushiro peat bogs.

1, humus; 2-6, peat (H3-H7); 7-10, *Sphagnum* peat (H2-H5); 11, clayey peat: 12, organic clay; 13, clay; 14, silt; 15, sand; 16, gravel; 17, volcanic ash; 18, timbers; 19, shells.

3. Formation of Buried Topography under the Plain.

Many borings of the depth of 50 m have been made along the Akan and the Ninishibetsu (Fig. 22). The author tried to understand the structure of the plain. Of course it goes without saying that an interpretation of the descriptions of the boring cores should be carried out carefully, because the author himself did not take part in the boring survey. The lower Pleistocene Kushiro formation composing the upland of the surroundings of the plain consists of clay, sand, gravel and volcanic ejecta. It is difficult to distinguish this formation from the Holocene deposits, because both are lithologically similar. In spite of this difficulty the following facts are pointed out: According to the geological section made with the boring data, the section is divided into two parts, the upper and the lower ones. The upper part shows relatively simple lithological facies and consists of clay and sand, while the lower part shows considerably complicated lithological facies and consists of sand and gravel. In the boundary of both there is a remarkable gravel bed. The former can be considered as the Holocene deposits and the latter the Pleistocene Kushiro formation, and also the gravel bed at the boundary of both layers is an individual fluvial deposit or terrace deposit.

From this point of view the author has found an area of several buried geomorphic surfaces, near the localities 28-3, 29-19 and 28-15, including the localities 30-16 to 30-20, and 28-30 to 28-37, as shown in Fig. 22. Especially the surface of 30-16 to 30-20 is roughly flat and gently inclined to the east. Among these surfaces valleys of the depth of 40 to 50 m are developed. At the locality 29-2 the depth of the valley is over 90 m. If the surface 30-16 to 30-20 which is situated in the mouth of the valley of the Ninishibetsu is regarded as a former alluvial plain, it extends to the gravel bed at the locality 28-30

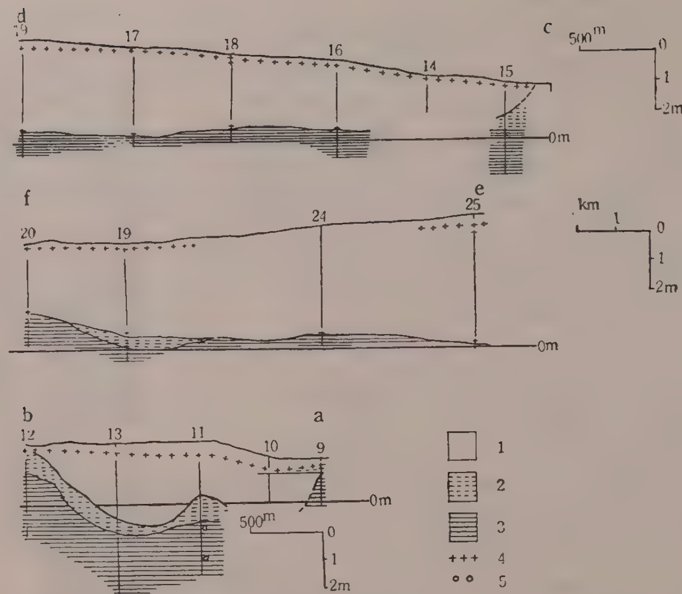

Fig. 21. Geological sections of the Kushiro peat bogs.
1, peat; 2, clayey peat and organic clay; 3, clay, silt, sand and gravel; 4, volcanic ash; 5, shells.

If this correlation is correct and if we might think the other surfaces also incline to the east, the surfaces lying near the localities 28-3, 28-14, 28-25 and 28-28 are well correlated to each other. The surface through the localities 28-12 and 30-11 also lies parallel to the former surfaces.

Concerning all the boring data the distribution of these geomorphic surfaces is shown in Fig. 23. Every surface inclines to the east and each gradient is as follows: I; 4.7×10^{-3}, II; 4.1×10^{-3}, III; 4.3×10^{-3}, and IV; 1.1×10^{-3}, that is, every amount of the past surface is greater than that of the present alluvial surface. These geomorphic surfaces are partly distributed under the alluvial plain of the Akan valley, and partly under the plain facing the Pacific Ocean. It is clear the former ones are river terraces or an old river bed, but it seems very difficult to say simply the latter are also river terraces. If the latter ones are fluviogenetic, it would also mean that the above mentioned inclinations of the surfaces were original. If marine, we should consider that the surfaces and tilted. According to the latest investigations, the geological structure of the Kushiro formation is a basin structure having the axis through Lake Tōro and Otanoshike, and warping down toward Lake Tōro. It is remarkable that the large valleys are situated only in the westside of the Kushiro plain, not in the eastside. Moreover, the axes of the valleys situated in the westside cross roughly at right angles to the axis of the basin. That is, these valleys are consequent to the former geomorphic surface. This fact show that the direction of the valleys was affected by the basin structure forming tectonics.

Two terraces (C- and T-terraces) are situated in the western part of the

surroundings of the plain. In the eastern part these terraces are seen only at two places. One of them, the Kushiro terrace, is correlated to the T-terrace. The other is seen at the northwest of Lake Tōro. All the river terraces correlated to the C- and T-terraces incline to the east and their gradients are greater than one of the present river bed. The margins of these terraces end to form a low cliff or dip below the alluvial plain. The gradient of the Shimohororo terrace surface is about 1.6×10^{-2}. The direction of the maximum inclination of this surface is oblique to the axis of the basin. Considering the above mentioned facts it seems to be possible to say the buried upper terrace is correlated to the T-terrace.

The altitudes of the marine terraces along the Pacific Ocean are unevenly lowered at the western part of this plain. Judging by this fact and the tilting of the river-terraces, the existence of a tectonic line or zone trending to the direction of the River Kushiro might be surmised. If the author's interpretation on the boring data collected in the southern area of this plain is right, the fact that the assumed buried geomorphic surfaces abruptly become lower may prove the existence of the tectonic line or zone. M. Minato has found out molars of *Mammonteus primigenius* in the deposit of the lower terrace situated in the Cape Erimo, the south end of Central Hokkaido, and he has regarded the age of this terrace as the Würm glacial age. As the author's T-terrace is correlated to the Erimo lower terrace, it would be considered the activities of this tectonic line or zone took place after the Würm glacial age.

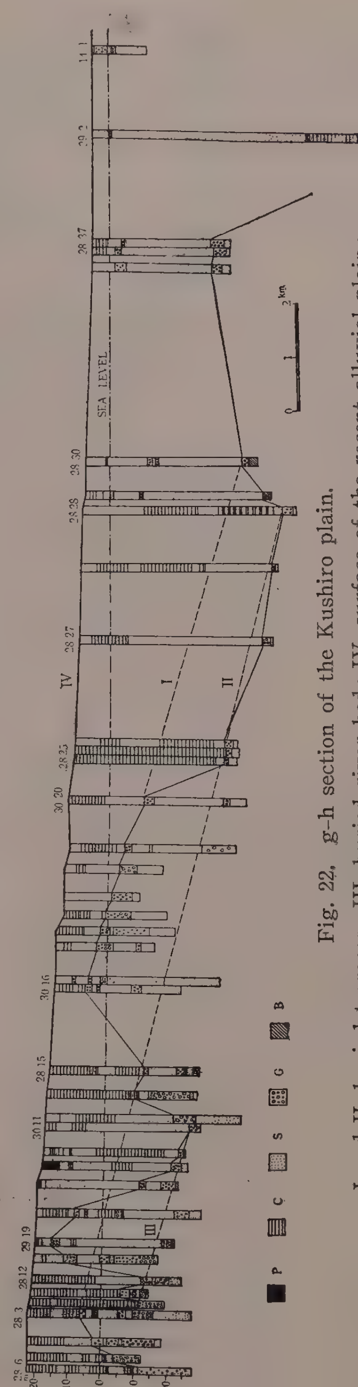

Fig. 22. g-h section of the Kushiro plain.
I and II, buried terraces; III, buried river bed; IV, surface of the recent alluvial plain; P, peat; C, clay; S, sand; G, gravel; B, base.

Fig. 23. Distribution of the terraces in the Kushiro plain and its surroundings.

1, C-terrace; 2, T-terrace; 3, K-terrace; 4, old river bed; 5, contour lines; 6, locality of the geological section; 7, assumed structural line or zone; A, subaerial surfaces; B, buried surfaces.

4. Formation of the Peat Bogs.

Afterwards the original relief was covered with the Holocene deposits. The transgression of the Holocene epoch at least reached Lake Tōro. There *Neomysis awatschensis*, one of the land-locked species is found. The maximum level of the transgression is 5 m judging by the height of the beach ridges (*Period of the Paleo-Kushiro Bay*). The following facts are sufficient to recognize that the whole territory of this plain has tilted to the north and the east from the beginning of the accumulation of peat:

1) Seeing the NS section of the plain, the base of the peat layer inclines to the north.
2) The River Kushiro flows along the eastern margin of the plain.
3) Almost all the rivers in the plain flow toward the east or the southeast.
4) The northern part of Shōwa area, north of the Ninishibetsu, inclines toward the northeast.

Such trend of the crustal movement as that mentioned above is very similar to that before the accumulation of the Holocene deposits. Y. OKAZAKI has carried out the pollen analysis on the samples collected from three peat beds lying in a range of 10 to 857 cm under the ground near Otanoshike. Judging by this result the deposits containing these peat beds are the terrestrial Pleistocene or the lowermost Holocene, consequently the surroundings of this sampling locality have never been covered by the sea. The change from the bay to the lagoon environment was considerably rapid, judging by the growth of the

deltas and the tilting of the bay. Afterwards the regression took place, and the lagoon changed to a swamp of the depth of less than 1 m. The accumulation of the peat began locally about 3,000 years ago. 2,000 to 3,000 years ago the peat bogs spread to the whole territory of this plain. The thickness of the peat layer is generally thinner than that of the Sarobetsu lowland, because this plain was an open water area being unfavourable to the growth of the emergent vegetation for a long time. Its cause seems to be due to a subsidence of the central part of the plain.

IV. Geomorphic Development of Ishikari Depression

1. Outline of the Region Investigated.

The Ishikari depression extends in the north-south direction from the Sea of Japan to the Pacific Ocean, and is filled with the sediments of the post-Tertiary and volcanic ejecta, and the most important tectonic zones by which Hokkaido is divided into the east and west geologic provinces. and which is also a boundary referred to the distribution of fauna and flora (Fig. 24). In the east side of this depression the Maoi anticlinal hill lies in the north-south direction, and in the west side there is the Shikotsu Volcano. The ejecta of the Shikotsu Volcano spread to the Maoi hill across the depression, and here lies the divide of an elevation of 20 m above sea level between both drainages of the Sea of Japan and the Pacific Ocean.

On the north of the Shikotsu Volcano there are the Nopporo anticlinal hill and the fan of the Toyohira being adjacent to the west of the hill. At the north end of this depression there is the Ishikari folding hill consisting of the Neogene formations and having the axes of the north-east-north direction. The lowland lying between the Maoi hill and the Nopporo hill is the most ill-drained area in the Ishikari Plain, and in its southern part there were considerably big lakes until a recent date, but now some of them have been reclaimed. The Sunagawa depression branches off from the neighborhood of the north end of the Ishikari depression to the north-east-north, and it is filled with the sediments of the post-Tertiary. Both margins of this depression border on the mountainlands with smooth lines. The Ishikari pours to the Sea of Japan running through this depression. The peat bogs chiefly spread in the interfluves of the south to Naie from which point the width of the plain suddenly becomes greater (an elevation of less than 20 m above sea level). The peat bogs in this area have not such continuity as of the Sarobetsu lowland or the Kushiro plain.

There run two sand dune ranges in the coast area. One of them is more or less 10 m above sea level and is situated in the present shore; another is about 20 m above sea level and is situated in the land of 5 km far from the shore line. The latter is called *the Momijiyama sand dune range*, the former *the Ishikari sand dune range*. The elevation of the sea-side foot of the Momijiyama sand dune range is 5 m above sea level. Between both sand dunes the beach ridges of less than 1 m in relative height are arranged in parallel lines. Around the depressions, except the slope of the volcanoes and the fans, terraces and terrace-like topography are found.

Fig. 24. Geomorphic map of the Ishikari depression.

1, oligotrophic peat bogs; 2, mesotrophic peat bogs; 3, eutrophic peat bogs; 4, T-terrace; 5, C-terrace; 6, Shikotsu welded tuff; 7, young volcanoes; 8, caldera wall (6–8, After M. MINATO and others); 9, alluvial fans; 10, localities of the sections; 11, peat sampling localities; 12, terraces covered by the volcanic ejecta; CA, Kaigan (Coastal) anticline; MS, Masarikappu syncline; SA, Shumbetsu anticline; TS, Tōbetsu syncline.
figures: elevations of the terraces in metres.

2. Geology of the Superficial Deposits.

According to the data collected by the Hokkaido National Agricultural Experiment Station and the Hokkaido Development Bureau the thickness of the peat layer is 7 m in maximum; in many cases less than 5 m, so far as the author is concerened. In Shinotsu area spreading along the right bank of the Ishikari south to Tsukigata, the thickness of the peat layer changes with the distance from the shore line. That is, at each point of 7, 12, 15, and 20 km the thickness of peat layers are 290, 265, 395 and 460 cm respectively. In the inner part than the last point mentioned above the thickness done not nearly exceed an amount of 7 m. Also the relation between the distance from the shore line and the thickness of the peat layers along the profile from the southwestern end of the Momijiyama sand dune range to Shiroishi area, northeast to Sapporo is as follows: 3.5 km : 85 cm, 7.5 km : 181 cm, 16.5 km : 600 cm. Namely the thickness becomes unevenly greater at the inner side of the Momijiyama sand dune range. This fact shows that the developmental process is slightly in both provinces divided by the Momijiyama sand dune range. Judging from the fact the thickness of the peat layer of any peat bog, which is in the innerpart than this dune

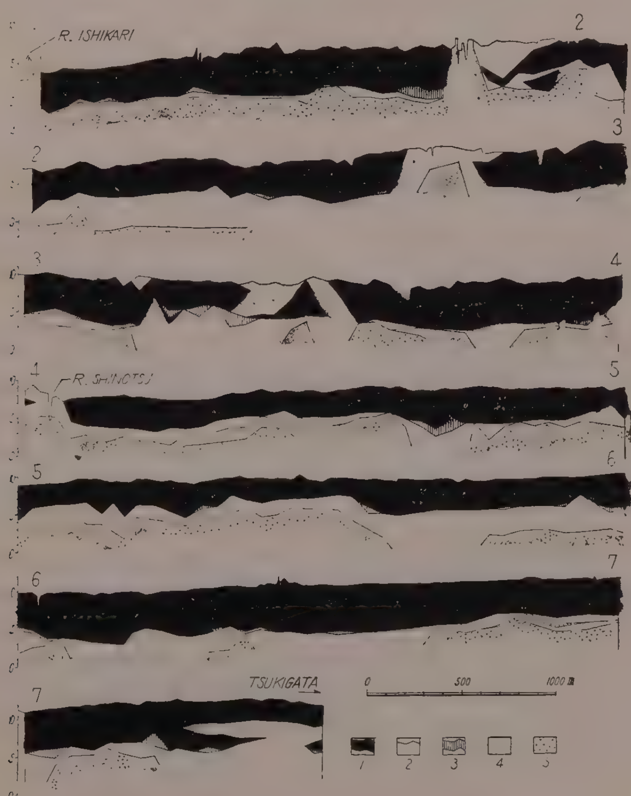

Fig. 25. Section along the Shinotsu Canal (drain).
1, peat; 2, clay; 3, peat clay and organic clay; 4, sand; 5, sand and gravel.

is not so variable, no matter that the peat bogs are independent of each other, the peat bogs are considered to have occurred roughly simultaneously.

The sequence of the superficial deposits at the section along the Shinotsu canal is peat, clayey peat, clay and sand or sand or sand-gravel in descending (Fig. 25). The bedding plane of the sand or sand-gravel bed is uneven. Some

Fig. 26. Geological division of the superficial deposits of the Shinotsu peat bog.

1, oligotrophic peat bogs. 2, mesotrophic peat bogs.
3, eutrophic peat bogs. 4, localities of the old river beds.
5, hand-boring localities.

depressions in this bed are regarded as old river channels. The bedding plane of the clay is roughly even; the clay seen at the present or the old river courses is contineously deposited to the surface. The distributing area of the clay does not exceed the width of 520 m at any locality. The settling of the river course is also recognized. The relatively thick peat layers are in the oligo- and meso-trophic peat bog areas. The accumulation areas of the clay are restricted in the narrow zones along the margin of the peat bogs or the river channels. In the surroundings of Tōbetsu Town there are three accumulation strips of the clay (Fig. 26). The north ends of these strips trend to converge at the Tōbetsu. The elevation of their southern ends is about 10 m above sea level. In the areas lying among them and between the Tōbetsu and the Ishikari hill, clay and peat are alternatively accumulated. Consequently, it seems the most fitting to consider this area is a raised delta.

3. Interpretation of the Boring Data.

The author made two geologic sections, A and B, taking up some the geologic columns of 130 localities (Figs. 27 and 28). According to the boring data, the

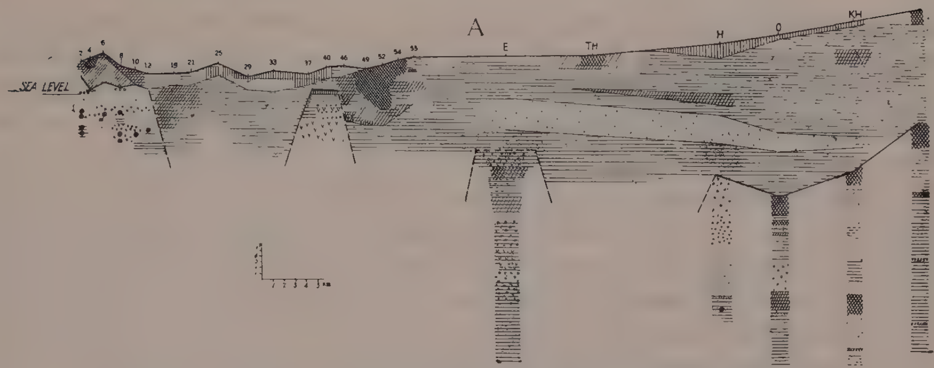

Fig. 27. A-section of the northern part of the Ishikari depression.
For explanation see Fig. 28.

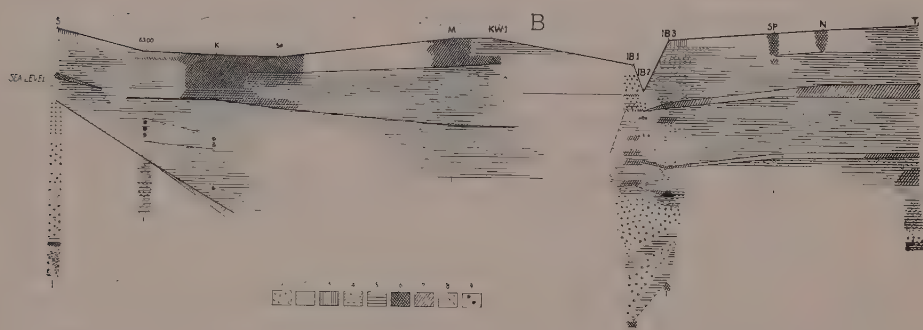

Fig. 28. B-section of the northern part of the Ishikari depression.
1, gravel; 2, sand; 3, loam; 4, silt; 5, clay; 6, peat and peaty clay; 7, humus; 8, volcanic ash; 9, shells; E, Ebetsu; TH, Toyohoro; H, Horomui; O, Ochanomizu; KH, Kamihoromui; I, Iwamizawa; S, Sapporo; K, Kakuyama; M, Mihara; KW1, Kawaminami Pump Station 1; IB1–3, Iwamizawa Ōhashi (Bridge); SP, Shinotsu Pump Station; N. Nakagoya; T, Tsukigata.

deposits are lithologically divided into two parts; the upper part shows simple lithological facies consisting of fine deposits such as clay, silt and sand; and the lower one shows complicated lithological facies consisting of the fine deposits and gravels. The buried peat beds are abundant in the east to Horomui, especially at the west of Iwamizawa sixteen layers are intercalated in the deposits with the depth of 300 m; also at Iwamizawa-Ōhashi (Bridge) eight peat or organic layers in the deposits within the depth of 50 m. At Kawaminami, south of Tōbetsu buried peat layers lie at the depth of 6.50 to 10.70 m (8.50 to 4.30 m above sea level) and 15.35–15.85 m (0.35 to 0.85 m above sea level), also at the depth of 3.20 to 5.20 m (5.7 to 3.8 m above sea level) at the locality Osatsu. According to the results of the pollen analysis the upper layer at Kawaminami is correlated to that of Osatsu. Shells occur in the sand-gravel beds at the southern extent of the Ishikari hill along the section A. Volcanic ejecta are contained in the deposits near the confluence of the Toyohira to the Ishikari and at Ebetsu. At Kakuyama (7 m above sea level), west of Ebetsu, under the peat layers of 6 or 7 m in thickness gray clay is accumulated till the depth of 26.53 m. The basal part

of this clay layer is humic, and overlies on the pumiceous sand deposit. There are two shell beds at the depth of 17.00 to 17.76 m and 25.02 to 25.68 m containing such shells as *Tapes* (*Amygdala*) *japonica* (Deshayes), *Anadara subcrenata*, *Ostrea gigas* and *Corbicula japonica* living in the littoral zone of the bay environment.

Judging by the above mentioned characteristic and the geology of the surroundings the author has correlated those deposits as follows:

1. The shell bearing sand shown in the section A would be correlated to the Zaimokuzawa formation, the Pliocene, consisting of unconsolidated silt, sand and gravel, occurred in the southern part of the Ishikari hill.
2. It would be considered that the volcanic ejecta or the pumice beds are identified with the Eniwa volcanic ashes or the Tarumae volcanic ashes covering the Nopporo hill.
3. The deposits with the peat layers appeared in the east to Horomui would be correlated to the pre-Holocene, perhaps the Pleistocene terrace deposits and the Nopporo formation.
4. The shell bearing deposits consisting of clay, silt, and sand, and peat layers overlying the former deposits are the Holocene.

4. Formation of the Pre-Holocene Landform of the Depression.

It has been considered that the Ishikari depression was formed by the tectonic movements during the post-Tertiary, and the formation of the Sunakawa depression was slightly later than that of the Ishikari depression. It is also known the Ishikari depression was a strait connecting the Sea of Japan and the Pacific Ocean, or a bay. They are called the Paleo-Ishikari Strait or Paleo-Ishikari Bay judging by the deposits there.

Moreover, the pre-Holocene landform was considerably different from the present features. The C- and T-terrace found along the southwestern coast of Central Hokkaido are tilted toward the eastern margin of the Ishikari depression, and T-terrace becomes very low (Fig. 29). According to the boring data of the locality AZ- No. 1 at Azuma (10 m above sea level) peat layers lie at the depth of 24.06 to 24.59, 33.00 to 34.20 and 64.10 to 64.35 m. The first is covered with the volcanic ash and the clay layers, but under this peat layer there are the shell bearing clay and sand-gravel beds. The author carried out pollen analysis on

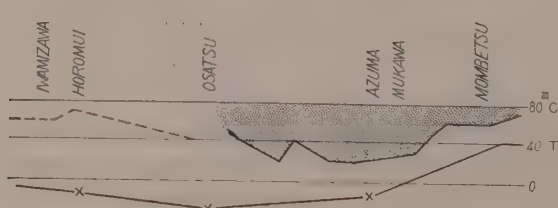

Fig. 29. Diagram showing the displacement of the raised shore lines along the east border of the Ishikari depression.

the samples collected from those three layers. But samples fitting the analysis are only the first because the pollen grains contained in the second and the third strongly decay. According to the results of the analysis the pollen spectra of the first layer are similar to those of the T-terrace deposits collected from other places of Hokkaido. The author identified the first peat layer to the T-terrace deposits. Thus the existence of the T-terrace which was expected to submerge under the alluvial deposits has been made sure.

A terrace-like landform found along the eastern margin has been regarded as a piedmont fan by T. NAGAO. This geomorphic surface continues the alluvial plain without a distinct cliff. The author regards it as the C-terrace surface tilted toward the plain. This explanation seems to be also applied to the feature of the terrace around the Nopporo hill. The T-terrace may be concealed below the alluvial surface in the eastern part of the Ishikari depression than a line through Tōbetsu and Ebetsu and the southern part of the Sunakawa depression. Seeing two terraces of the Ikushumbetsu and Horomui which are correlated to the C- and T- terraces, each terrace of both rivers dips below the alluvial surface. This phenomenon seems to be related to the subsidence of the above mentioned two depressions. The author recognized the existence of the T-terrace surface under the alluvial surface at Osatsu. The peat bed lying at the depth of 40.40 to 45.60 m at Osatsu is correlated to the T-terrace deposits according to the results of the pollen analysis. The surface of this bed is at 31 m below sea level. This bed is covered with the volcanic ash layers. Especially the volcanic ejecta lying at the depth of 20.00 to 37.20 m appears at two localities situated in the neighborhood of this boring locality. The volcanic ejecta would be regarded as the Shikotsu welded tuff which erupted during the Shikotsu caldera forming activities. M. MINATO has considered the eruption age of the welded tuff is the late stage of the Würm glacial age. The author considers this eruption age as the time after the formation of the T-terrace peat deposit or before the formation of the Holocene deposits, perhaps the earliest Holocene.

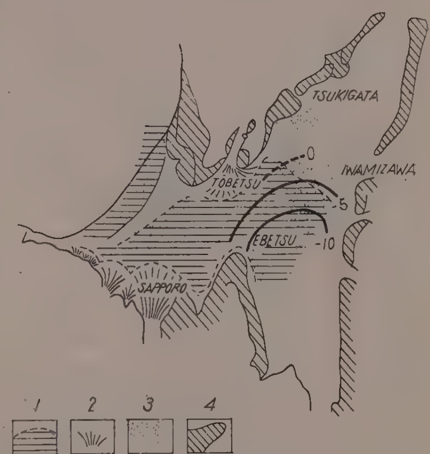

Fig. 30. Paleogeographical map of the northern part of the Ishikari depression.
1, sea in the maximum stage of the transgression of the Holocene epoch; 2, alluvial fans; 3, land in the beginning of the transgression of the Holocene epoch; 4, terraces.

The ages of the geomorphic surfaces lying below the alluvial surface of the Sunakawa depression, likely lying below the alluvial surface near Ebetsu and the confluence of the Toyohira are not yet decided. It is very interesting that the first geomorphic surface becomes lower toward the south, that is, 3 m at Tsukigata, 1 m at the pump station of the Shinotsu main canal, −4 m at

Iwamizawa, and −14 m at Horomui in absolute altitude (Fig. 30).

Around the Ishikari hill there are four or five main marine terraces, more than in any other area around the Ishikari Plain. This peculiarity may be explained by the activity of the anticline running from north to south during the terrace forming periods. As above-mentioned, the deposits regarded as a member of the Pliocene are found at the underground extremely near the alluvial surface just situated in the extent of the Ishikari hill. This fact seems to show the activity of the geological structure.

5. Change of the Sea Level and the Formation of the Peat Bogs.

Judging by the distribution of the Holocene doposits the shore line when the transgression reached the maximum level is presumed as shown in Fig. 30. The elevation of the shore line at that time was about 5 m above sea level judging by the maximum height of the beach ridges. However, as the coastal area belongs to the upheaval zone and another part of the plain to the subsidence zone, the former shore line situated in the coastal area should be lower than 5 m above sea level actually. The base of the oldest superficial peat layer is near the sea level. As a thickness of peat layer succesively accumulated is 5 m and less than it is in most cases in the transgression area of this plain, its age is estimated at 5,000 or 6,000 years. Even though the peat layer of 7 m in maximum thickness consists of the pure peat only, the beginning of the accumulation of the peat in the transgression area of the Ishikari Plain can not be more than 8,800 years ago. After the transgression reached the maximum level, the sea level stayed almost the same for a long time. During this period the bay became shallower by deposition. Around the bay deltas advanced toward the sea. On the deltas backswamps were formed everywhere. At the same time a sand dune range was formed on the upheaval zone. Judging by the arrangement of the beach ridges it seems that the regression has smoothly been done to the present shore line. The author has no proof for the opinion that the shore line has been lower than the present sea level. However, if the cliff in front of the Ishikari sand dune were formed by wave erosion, it may be considered a minor transgression occurred. Even at Tsukigata where was the land during the transgression the thichness of the peat layer does not exceed 7 m. This fact seems to teach us that the existence of spaces available to form peat bogs only is not sufficient condition for the formation of peat bogs. The peat bogs occurred simultaneously in both non-transgression and transgression areas of the Ishikari Plain 5,000 or 6,000 years ago when the necessary and sufficient conditions for the accumulation of peat were ready.

V. Geomorphic Development of Peat Bogs in Tokyo and its Surroundings

1. Outline of the Region Investigated.

The region north of the Tokyo Bay from Kawasaki to Chiba is composed of the Musashino, Ōmiva and Shimōsa diluval uplands, valley plains in the

Fig. 31. Morphological map of the main part of the Kantô Plain (After S. KAIZUKA).

1, alluvial plain.
2, upland.
3, hilly land.
4, mountain land.
5, volcano.

uplands, and alluvial plains along the Tamagawa, Arakawa, Nakagawa and Tokyo Bay (Fig. 31). S. KAIZUKA has investigated the earth history of the Kantō Plain. The surfaces of the uplands in the Kantō Plain are covered with the Kantō Loam. KAIZUKA and others have successfully carried out the correlation of the geomorphic surfaces by the Kantō Loam. Tokyo City District is geomorphologically divided into two parts, so-called Yamanote on the Musashino upland and Shitamachi on the lowland along the Bay. The geomorphic surfaces of the Musashino upland are divided into three; Yodobashi, Musashino, and Tachikawa in descending order. The Yodobashi surface has been considered an accumulation surface consisting of the Tokyo formation, the Pleistocene deposits of the Paleo-Tokyo Bay. The Musashino surface lying at the level of 5 to 10 m lower than the Yodobashi surface, is a raised alluvial fan. Its eastern part consists of the estuarine deposits. The Tachikawa surface is found along the Tamagawa and its southern part is dipped below the alluvial surface. KAIZUKA has correlated the buried surface lying under the mouth of the Tamagawa (the maximum depth : 60 m) to the Tachikawa surface or a surface lying directly below this surface.

The buried geomorphic surfaces lying under the Shitamachi coastal plain are divided into three. The upper surface is distributed at the depth of 10 m and less than that along the margin of the upland, especially the areas between Ueno and Ryōgoku, and the Tokyo and Shimbashi Stations (Fig. 35). This surface was formed at the same time with the formation of the cliff of 15 to 20 m in relative height found along the eastern margin of the upland, that is, during the transgression of the Holocene. The middle surface is well developed

on the east of the Arakawa at the depth of 30 m. The lower surface is a former valley bottom. Its depth reaches 60 m below the surface even in the Arakawa lowland or at the mouth of the Tamagawa. On the buried surfaces the valleys are found and some of them are connected with the valleys dissecting the upland, that is, Shinobazu, Kandagawa, Megurogawa, Nishi-Magome and Ikegami valleys.

The surface of the Ōmiya upland is correlated to the Yodobashi surface. This upland consists of clay, sand, and gravel, and is surrounded by the alluvial plain. The relative height between upland and alluvial surfaces becomes smaller toward the northeast, while it is about 10 m at the southern and western side of the upland. The Shimōsa upland also consists of clay, sand, and gravel. This surface has been correlated to the Yodobashi surface according to Kaizuka. The Nakagawa lowland consists of the deltaic deposits of the Tone and the Arakawa. Many natural levees running complicatedly are seen on the lowland. The changes of a river course before the historic age are, however, not yet studied.

The peat bogs are distributed in the valleys, especially in their lower courses and the Nakagawa lowland.

2. Formation of the Kemigawa Peat Bog and Changes of the Sea Level.

This peat bog is situated in a valley dissected in the Shimōsa upland. At the mouth of the valley a sand bar of 7.5 m above sea level is found (Fig. 32). The 2.5 meter-contour is closed in the valley. The uppermost part of this valley is connected with the opposite-side valley by a narrow canal. At the

Fig. 32. Topography of the base o the peat layer of Kemigawa.

●, boring localities; ⊗, sampling localities of the peat; E, The canoe and the seeds of lotus have been excavated at this site; P, pump station; W, Kemigawa Wireless Station.

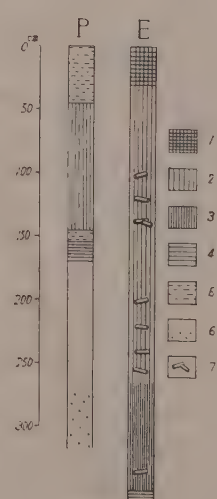

Fig. 33. Columnar sections of the peat layer.

1, peaty soil; 2, dark brown peat; 3, gray-black peat; 4, clay; 5, silt; 6, sand; 7, timbers.

locality E the thickness of the peat is 320 cm (Fig. 33). The decomposition grade of the peat is relatively low, H3 in general, but H5 at the lower part. The peat layer overlies conformably on the gray clay deposits, and the elevation of both boundaries is 4.5 m above sea level. One ancient canoe and seeds of the lotus have been found at this boundary. Though the horizon of the seeds of the lotus is not so clear, we may be sure the seeds were contained in the clay deposit judging from one of the natures of the lotus that it is difficult to grow with *Phragmites*. According to the result of the Carbon-14 dating method the canoe is of 1122±180 B.C., that is, of the late Jōmon period. I. ŌGA has succeeded in an examination of the budding of those seeds. The peat layer and clayey peat layer are extended in the whole area of this valley. Their thicknesses are not uniform, but the layers trend to become thick toward the upper part of the valley.

The deposits underlying the peat layer consists of clay and sand with shells. The shells are traced to Amado by matter which was taken from the bottom of the Hanami at the time of the dredging works. These shells may be correlated with those found at the boring column of No. 8 (Fig. 34). If this cor-

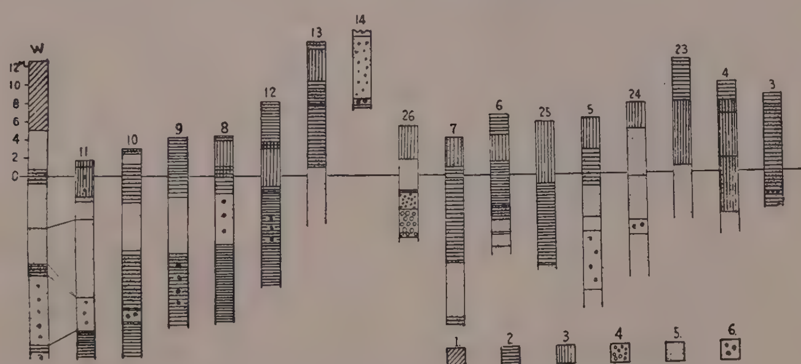

Fig. 34. Columnar sections of the Kemigawa valley.

1, Kantô Loam; 4, gravel;
2, clay; 5, sand;
3, peat and peat clay; 6, shells;

relation is right, the sand layer at the columns of No. 9 and No. 10 and the uppermost of sand layer at the column of No. 11 may be also the same as the Holocene. In this case the maximum depth of the base of the Holocene would be 8.5 m below sea level. The geomorphic surface before the accumulation of peat is roughly even and its elevation is approximately equal to the sea level.

The transgression of the Holocene epoch reached at least Amado of the main valley. If the seeds and the canoe had been found in the same horizon, the water body in the valley should have changed to the fresh-water at least by the late Jōmon period. This change of the environment was done by the development of the sand bar at the mouth of the valley. There are many springs along the margin of valleys in such diluvial uplands because these valleys often cut aquifers. In many cases this spring water is an important

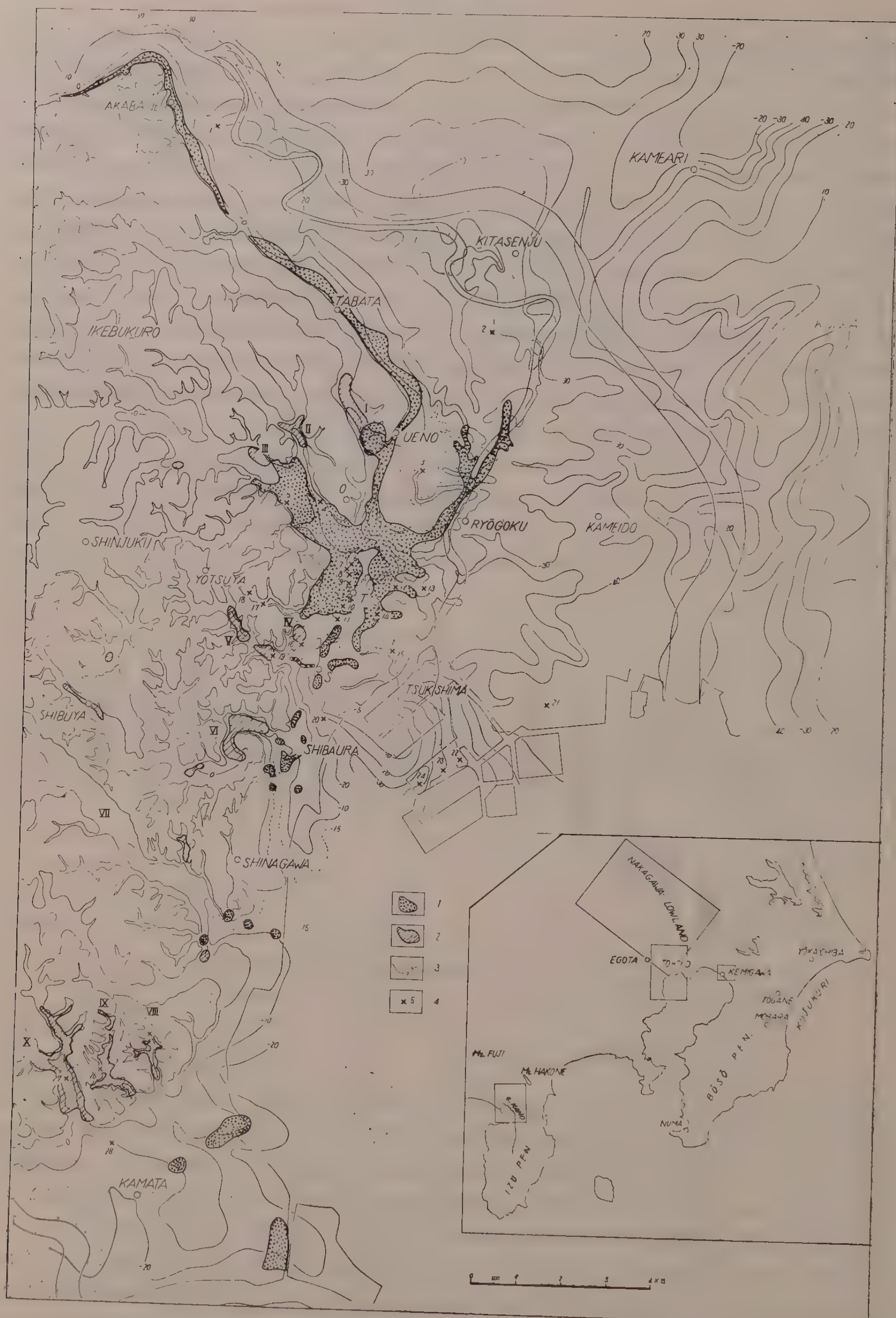

Fig. 35. Distribution of the peat bogs and the buried topography under the Holocene deposits in Tokyo.

1, Marunouchi gravel bed; 2, peat bogs; 3, contour lines of the buried topography in metres; 4, buried humus beds (figures: locality numbers); I, Shinobazu valley; II, Sashigaya valley; III, Edogawachô; IV, Kasumigaseki; V, Tameike valley; VI, Shibuyagawa valley; VII, Megurogawa valley; VIII, Higashi-Magome valley; IX, Nishi-Magome valley; X, Ikegami valley; O, Ochanomizu; T, Tokyo Station; S, Shimbashi Station.

factor to help the accumulation of peat. As we can see springs along the margin of the Kemigawa valley everywhere, it may be sure that the change of the environment in the Kemigawa inlet at that time was promoted not only by surface and meteoric water, but also by this spring water. As a sand bar generally develops during the transgression or the time when the sea level does not move, the lagoonal environment in the Kemigawa valley had already been formed when the transgression reached the maximum level. The maximum sea level at that time was 7.5 m higher than the present sea level judging by the height of the sand bar. The author considers that the difference between the sea level at the end of the transgression and that during the late Jōmon period was very little, because the elevation of the locality E is 4.5 m above sea level, it is necessary that this locality was covered by water of more or less 1 m in thickness at that time.

3. Peat Bogs in the Lowland of Tokyo.

According to the illustrated book, *Geology of Tokyo* (*Tokyo-Jiban-zu*), peat bogs are found in the valleys, except near Kasumigaseki (Fig. 35). The maximum thickness of the peat layers ranges 2.0 to 9.0 m. The peat layers are commonly covered with reclimed soils or clay layer of 3 m and less than it in thickness. The peat bogs are found partly on the ground consisting of the Pleistocene formations, partly on the Holocene deposits. In the latter case the Holocene deposits are thin in general, about 8 m in maximum, 5 m and less than it in many cases. The elevation of the base of the peat layers ranges 6 m above sea level to 1 m below sea level. At the Shinobazu valley peat accumulates thick near the margin of the valley, but thin at the center of the valley, only 0.45 m at the Shinobazu Pond. The causes of this diferrence are the accumulation of peat was promoted by the spring water near the margin of the valley, and at the lower part of this valley there was such a water area as an emergent vegetation could not invade toward its centre at least till 340 years ago. At the Tameike valley a peat layer is thick in the upper part of the valley. At the lower part of the valley the peat layer is covered with the clay deposit of 2.6 m in thickness, because a pond was made here. The peat bogs at Kasumigaseki, the centre of the govermental offices, lies near the foot of the cliff of the upland, not in the valley. Natures of these peat bogs are not yet clear.

The thickness of the peat at the Higashi-Magome valley is 9 m in maximum. This amount may be the largest one not only in Tokyo, but also in Japan, if *peat* in that book were composed of pure organic material as the peat defined by the author. At the Nishi-Magome valley the peat layer is covered with the clay deposit of 3 m in thickness. The peat layers of both valleys directly overlie on the Pleistocene formations. These peat layers seem to be the oldest in Tokyo. At the Ikegami valley peat or organic clay is accumulated on light gray clay deposit (Fig. 36). The thickness is 4 m in maximum. The old sand spit is extended from the west corner of the mouth of the valley. Many springs along the margin of the valley are also an important factor for

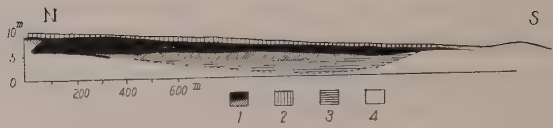

Fig. 36. N–S section of the Ikegami peat bog.
1, peat, peaty clay and black clay; 2, redeposited Kantô Loam; 3, clay; 4, silt and sand.

the growth of the peat bog. The peat layer is covered with dark brown clay layer of 1 m in thickness. This clay layer is the secondary Kantō Loam transported from the upland. Consequently its thickness is especially large at both sides and the head of the valley. This deposit exists only on the surface of the peat layer. From this fact it may be said this clay layer is the latest deposit and such conditions as the Kantō Loam on the upland was brought to the bottom of the valley were not ready at least during the accumulation of the peat. We can see such a phenomenon everywhere on the valleys of the uplands in the Kantō Plain. The author considers this phenomenon would show the soil erosion which was brought on by the reclamation of the uplands during the recent historic age. At the Ikegami valley the geomorphic condition for the peat bog forming was completely satisfied by the formation of the sand spit. But, at the Higashi- and Nishi-Magome valleys a sand spit is not found anywhere. An inclination of the bottom of both valleys is slightly steep at the mouths at 5.5 m to 7 m above sea level. The positions of the change point of the inclination coincide with the sea-side margin of the peat bog. The cliff of the alluvial terrace of 7 m to 9 m in elevation lying along the upland near the Ōmori Station continues to the above mentioned change point. The Ōmori shell mound of the late Jōmon period lies on the surface of this terrace. It is assumed that the maximum sea level was 7 m to 9 m higher than the present one judging by the altitude of this terrace and the altitude of a sandbar-like relief lying at the mouth of the Meguro valley. At the Ikegami valley a shell mound (the shells almost marine) of the late Jōmon period was situated on the upland 2 km from the mouth of the valley. From this result we can understand the sea was near this shell mound till the late Jōmon period. As the elevations of the bases of the peat layers at the Higashi- and Nishi-Magome valleys are 2 m and −1 m respectively, both bases should be covered by sea water during the transgression. Notwithstanding, both peat layers directly overlie on the Pleistocene formations. Namely, the Holocene deposits are absent there. From this fact it is considered that at both valleys the accumulation of peat occurred before the sea level reached the maximum. If the peat of the Higashi-Magome valley were composed of pure plant remains, the peat layer of the Higashi-Magome valley would be as old as 9,000 years.

The Yūrakuchō formation, the Holocene deposits in the Tokyo Bay, is divided into two parts, the upper bed and the lower one, by K. SUZUKI and others. The lower bed consists of clay, silt, and sand with shells of *Ostrea* sp., and *Anadara granosa*; and *Anadara granosa* is found as fossil at the shell

mounds of the early Jōmon period in the Kanto Plain. It does, however, not live today in the Tokyo Bay, but in the Pacific coast of Japan west to it. The thickness of the Yūrakuchō formation is very thin in the western area as compared with the eastern area from the Sumida. In the western area the Marunouchi gravel bed lies on the Tokyo formation, one of the Pleistocene formations (Fig. 35). According to K. Suzuki and others the upper Yūrakuchō bed is unconformably covered with the lower Yūrakuchō bed, and its unconformable surface is somewhat undulated. The peat layers are chiefly accumulated on the Marunouchi gravel bed in the middle part of the valleys, and on the upper members of the lower Yūrakuchō bed in the lower part of the valleys. We can often see humus beds at the lowermost of the Yūrakuchō formation (Fig. 35). It is interesting that most of such humus beds are at the upper part of the valley slope. Their depths below sea level are as follows: −0.5 m at Iidabashi, −6 to −9 m around the Tokyo Station, −17 m at Uchisaiwaichō, and −25 m at Tsukiji. These humus beds are found everywhere in the lowland of Tokyo under the Yūrakuchō formation. Although the natures of these humus beds are entirely unknown, the author considers them as either the A-horizon of a fossil soil or deposits composed of the organic matter which was transported from the surroundings to the coast at the transgression. It is, however, not clear why they are chiefly situated in the upper part of the valley slope.

4. Minuma Peat Bog.

The Minuma valley is the greatest of the valleys which have been formed in the Ōmiya upland. This valley changes to the narrow and shallow one at Haraichi, although the relative height of this valley is about 20 m at its mouth (Fig. 37). Along both valley walls near the mouth the alternating bed consisting of sand and clay crops out under the Kantō Loam. At Ōsado, however, we can not see such a bed. The bottom of the valley is very even. The natural levee of the old Arakawa is seen at the mouth of this valley. The peat bog of this valley changed to the pond since an earth dam was constructed at Hatchō in the first half of the 17th century. The water level of the pond seems to be at 8 m above sea level. This pond was dried up in the first half of the 18th century.

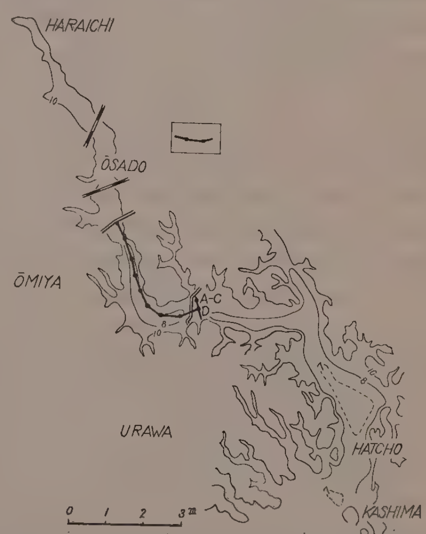

Fig. 37. Outline of the Minuma valley. Legend: localities of the sections shown in Figs. 38 and 39. The figures show the absolute elevations in metres.

The sequence of the deposits in the valley is roughly uniform (Figs. 38 and 39). The deposits composed of organic matters are at the uppermost part, 3 m

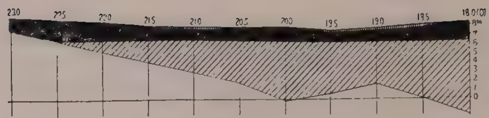

Fig. 38. Geological section through the Minuma valley.
interval of the bench marks: 500 m. vertical line: secondary deposit of the Kantô Loam. black part: peat, muck and black clay. oblique line: gray clay.

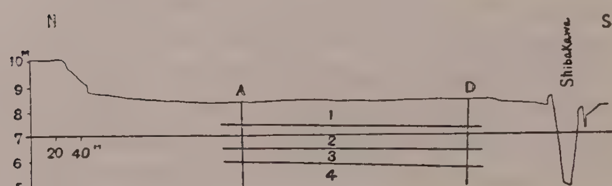

Fig. 39. N–S section through the bench mark 18. 0.
1, muck; 2, peat; 3, peaty clay; 4, gray clay.

and more than it in thickness, but the peat layer itself is not so thick except the branches of this valley, generally less than 1.5 m in thickness, and 3 m in maximum at the branches. The peat chiefly consists of *Zizania latifolia*, and sometimes contains fruits of the *Trapa* at the lower part, and lies on the clay bed. According to the result of the micro-fossil analysis of the samples at the locality A, *Melosira* sp. is found less than 2.4 m under the surface, while *Coscinodiscus* sp. is found more than 2.6 m under the surface. Judging from this result the change from the saline water environment to the fresh water one took place repidly at the depth of 2.6 to 2.4 m.

The geology of the valley is shown in Fig. 38, as referred the results of the electric prospecting. As the elevation of the accumulation surface of the saline water deposit is about 6 m above sea level, the sea level at that time must have been higher than this amount. At the Shimpukuji valley, east of the Minuma valley, the base of the peat layer reaches as far as 6 m under the surface, and the remains and the relics of the late Jōmon period are preserved in the peat layer at the depth of 3 m. The accumulation of peat at the branches of the Ayase and the Minuma valleys began earlier than every main valley, before the late Jōmon period. The age of the Minuma peat is calculated about 1,200 years when we regard its average thickness as 120 cm. Adding the age since the construction of the pond, about 300 years, and that of the muck to that amount, the age since the beginning of the accumulation of peat here should exceed 1,500 years. Though the calculation of the age of the peat layer is carried out under careful consideration, it is not considered that the beginning of the accumulation of the peat goes back to the late Jōmon period. Consequently, there is no doubt that most of the Minuma main valley was occupied by water for some time after the late Jōmon period.

5. Nakagawa Lowland.

As shown in Fig. 41, the sequence of the superficial deposits at the Nakagawa lowland is very different. So far as the result of the boring concerned, the peat layers are covered with the secondary Kanto Loam, silt and clay, but do not appear on the ground surface. The thickness of the peat layer is 0.8 m at No. 3, 1.8 m or more than it at No. 6, 1.8 m at No. 7, and 0.6 m at No. 9. It may not exceed 2 m anywhere. Especially, it is interesting that the clay deposit with the fruits of *Trapa* is accumulated on the peat layer or the organic deposits in the upper stream-side than the boring locality No. 5. This fact shows the environmental change from a marsh to a lake.

According to the precise topographic map, there are three very clear change zones of the inclination extending roughly east to west. The elevations of these zones are 2 m to 3.5 m, 4 m to 6 m, and 7 m to 10 m respectively (Fig. 40). According to K. Iseki's investigation, the change zone at Shiodome crnsists of sand with shells of *Ostrea*. He has considered this zone as a raised long-shore bar. The old channel of the Arakawa extended over this zone. Why did the Arakawa at that time flow in such a place? Iseki has explained it as follows: the former Arakawa could not flow toward the south because of the existence of the sand bar. The other two zones may also be explained in this manner. As each zone is considered to show a stable state or slight rise of the sea level, the uppermost zone would be regarded as the shore line at the maximum time of the transgression, and the middle and the lowermost zones as the shore lines at the time of a stable state or slight rise of the sea level during the regres-

Fig. 40. Geomorphic map of the Nakagawa lowland.

1, natural levees; 2, contour line; 3, boring localities; 4, hand-boring localities; 5, Shimpukuji relics; 6, peat deposits found within 1 m below the surface; 7, change zones of the inclination.

sion. The accumulation of the marine clay in the Minuma valley would have been taken place during the regression, the time when the shore line shifted from the uppermost zone to the middle one. Also, the accumulation of the peat in the Minuma main valley and the Nakagawa lowland north to the middle zone would chiefly begin at the time when the shore line shifted from the middle zone to the lowermost one. According to N. SAKAZUME's data, the shell mounds of the late Jōmon period are distributed Kasukabe situated between the uppermost and middle zones. Therefore the formation of the middle zone would have been taken place after the late Jōmon period.

Summarizing the results of the boring (No. 11–No. 21 in Fig. 40) the shell bearing clay bed of 25 m more than in thickness underlies the sand bed of 8 m in maximum thickness in the lower stream-side area than Satte. In the upper stream-side area, however, the clay layer overlies on the shell bearing sand layer of 5 m or more than it in thickness. The maximum level of the top of the shell bearing bed is 5 m above sea level at No. 20. Why is the sequence of the deposits different in both areas? Why is the fine material such as clay deposited in the upper stream-side, not in the lower stream-side? The author considers these features were brought by the Kantō basin forming movement. Many geologists have pointed out that the Cenozoic systems in the Kantō Plain have warped down toward the neighborhood of Kurihashi, situated in the central part of the Kantō Plain, and have called a tectonic movement formed such a geologic structure the Kantō basin forming movement. That the marginal part of the Kantō Plain is higher than the central part is considered to be a result of this movement. That the boundary between the upland and the al-

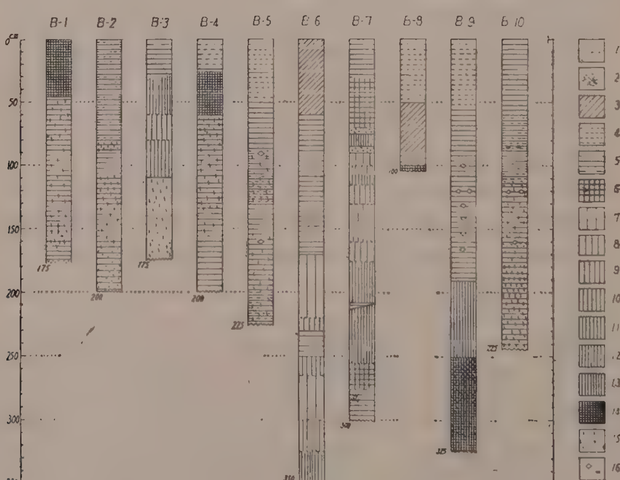

Fig. 41. Columnar sections of the Nakagawa lowland.

1, coarse sand; 2, fine and medium sand; 3, loam; 4, silt; 5, clay; 6, clayey peat; 7, peat of H2 of the decomposition grade; 8, peat of H3; 9, peat of H4; 10, peat of H5; 11, peat of H6; 12, peat of H7; 13, peat of H8; 14, muck; 15, plant remains; 16, fruits of Trapa sp. (left) and seeds of various plants (right).

luvial plain is not clear at the northeastern part of the Ōmiya upland, may also be explained as a result of this movement. Namely, as the upland tilted toward the northeast, the alluvial deposits covered the northeastern part of the upland. The fact that such a movement still continues is clear from the results of the precise levelling carried out after the Great Kanto Earthquake of Sept. 1, 1923. The intensity of this movement is never uniform in the Kantō Plain everywhere. According to Y. Ōtsuka the depth of the lower Pleistocene formations in the Kantō Plain becomes suddenly deep at Kōnosu toward the centre of the basin around Kurihashi (Fig. 42). The amount of the vertical displacement of the bench marks of the precise levelling during 34 years from 1892 to 1925 is very large in the northern area than Satte. Namely these results show the mode of the movement of the northern area than a line through Kōnosu and Satte is considerably different from one of the southern area than this line. The clay layers which have accumulated on the surface of the northern area than Satte, and the clay layers covering the peat layers would be considered to have accumulated because a gradient of the plain surface decreases due to this movement.

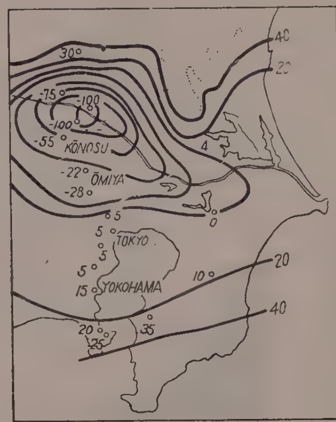

Fig. 42. Surface of the lower Diluvial series in the Kantō Plain (After Y. Ōtuka). This map shows that the surface of the lower Diluvial series inclines toward the neighborhood of Kurihashi Town from every direction. The strata of 1000 m in thickness including the Pliocene and Diluvial series have warped down as a basin having the center at Kurihashi.

VI. Ceomorphic Development of Kanogawa Alluvial Plain

Mt. Fuji is the young volcano which was formed in the Holocene epoch between the Volcano Ashitaka and the volcano Paleo-Fuji. In the beginning of the Holocene epoch, a large amount of lava overflowed in the valley between the Volcano Ashitaka and the Volcano Hakone. The lavaflow is called *Mishima lavaflow*, and its thickness is about 90 m and its base is about 100 m below sea level. Its southern end is not yet exactly defined, but according to N. Kurata its boundary may be traced as shown in Fig. 43. The Southern part of the Mishima lavaflow is bordered by the alluvial plain, consisting of the consolidated basaltic scoria bed and the black and light brown clay bed. The Mishima lavaflow and the southern alluvial plain are microscopically recognized as a very beautiful fan-shaped landform, but the lavaflow and the alluvial plain are covered with only the boulder bed of a few metres in thickness, and in a great part of this region the lava and the scoria beds crop out on the surface of the ground.

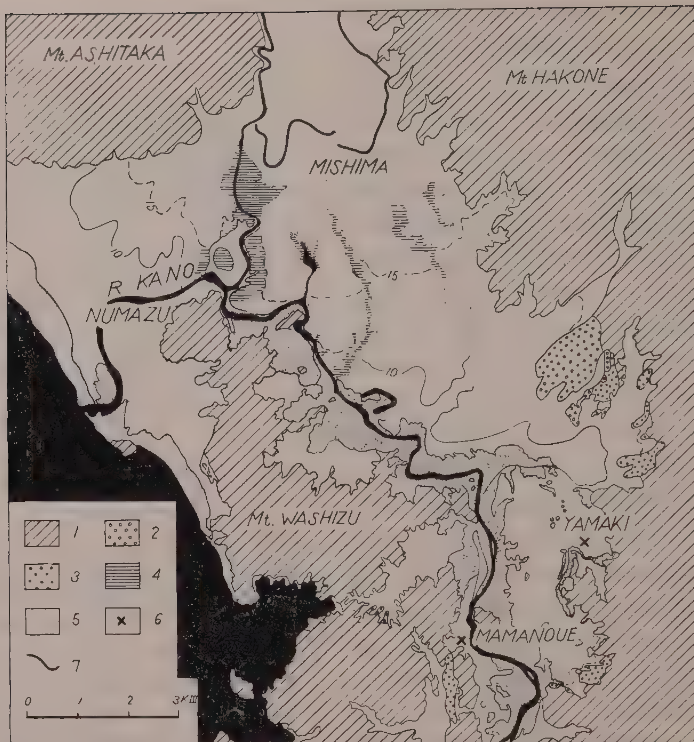

Fig. 43. Geomorphic map of the Kanogawa alluvial plain.
1, mountain land; 2, Hirai terrace; 3, Hatake terrace; 4, middle terrace of the alluvial plain; 5, natural levee and beach ridge; 6, site of relics; 7, boundary of the Mishima lavaflow.

At the eastern suburbs of Numazu City the scoria bed contacts with the Washizu mountainland, consisting of the Neogene volcanic rocks, and the Kanogawa incises about 10 m into this plain. In this region three terraces, the upper, the middle and the lower, are formed. The upper is the accumulation surface of the scoria bed, and partly the middle is divided from the upper by a cliff, partly continues from the upper without any distinct cliff, and the lower is the recent erosion terrace. At the terrace cliff at Sekishita of Numazu City, the brown and black organic clay bed with plant remains crops out from the river surface to 2 or 2.5 m above sea level. At the western site of 1 km in distance from this point along the river, the shell bed was found at about 1 m above sea level. In the southern suburbs of Numazu City an accumulation-terrace, about 15 m in height, fringes the foot of the Washizu mountainland. This terrace was formed in the Holocene epoch. Along the coast, a dune ridge of 5–10 m in height is formed, and at the inside of this dune ridge the peat bog of Ukishimagahara is found. Between the southwestern slope of the Volcano Hakone and the western slope of the volcano Taga, which are fringed by the Neogene volcanic rocks and Pleistocene terraces, and the Washizu mountainland, the Kanogawa alluvial plain extends.

Two relics of the late Yayoi period have been found recently. It is remarkably interesting that both relics were in the marshy land, and the rice-culture was carried on there at that time. From the trench cutting in the vicinity of Nirayama, the blue sand bed was found at the depth of 30–50 cm under the surface soil. A valley of 40 m in width and 2.5 m in depth incises the surface of this blue sand bed. This underground valley is buried by peat. From the lower part of this peat bed the earthen and wooden wares of the late Yayoi period were excavated.

In the neighborhood of the Izu-Nagaoka hot springs, in the Mamanoue lobe-shaped plain, the relics of the late Yayoi period were also found from the upper part of peaty clay bed, intercalating pure peat beds. The sequence of the deposits consisting of this plain is as follows: (I) brown sandy clay bed with débris, (II) sand, clay, peaty clay and peat beds, (III) sand and gravel beds, (IV) organic and clay beds, (V) clay bed with fossils of the mollusca which

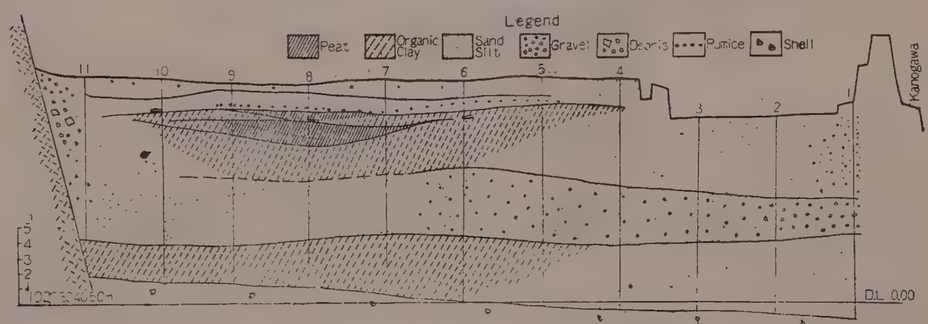

Fig. 44. Geological section through Mamanoue.

lived in the littoral and inner sublittoral zones in a bay (Fig. 44). Today in Japan such fauna chiefly live in the sea south of the Tanabe Bay. It is also interesting that there are many pumices sporadically through all horizons. Generally in the western part of this small plain the deposits are finer and more organic than those in the eastern part.

Hence the earth history of the Kanogawa alluvial plain may be summarized as follows:

1) The initial features of the Kanogawa and Mishima valleys were formed in the latest Pleistocene.
2) The recent volcano Fuji began its activiey in the early Holocene epoch, and a large amount of basaltic lava, namely, the Mishima lavaflow issued.
3) At the same time or a little later subsidence happened all over this region and the sea transgressed and the marine shell-bearing clay was deposited in this drowned valley. The author calls this inlet *the Paleo-Kano Bay*. The amount of this subsidence was about 100 m.
4) After the Paleo-Kano Bay was nearly filled up by deposits, the upheaval of the land began, and deposits changed to organic clay with plant remains from the marine deposits, and after this changing sand and gravel gradually deposited under the subaerial condition.

5) At that time a great deal of ash and scoria pushed down from the northern region to the surroundings of Mishima lava flow, dammed up the former Paleo-Kano Bay area and its lower part became swampy. At the later stage of that time human beings lived on the slightly dried ground around the peat bog. The dam site was broken by erosion of the riuer, and the swamp were drained, and terraces were formed. The total amount of the regression may be 15 m. Under the regression this region tilted slightly toward the west. Now, we have recognized that the formation of the peat bogs began for the first time in the late Yayoi period.

The most important problem here would be why the accumulation of the peat occurred only at that time, or why settlements of the prehistoric men were made in such a swampy place.

VII. Geomorphic Development of Ozegahara

1. Introduction.

Ozegahara is situated in the mountainland north of the Kantō Plain, and its elevation is 1,400 m above sea level. It is the largest typical *Sphagnum* peat bog in Honshū. Ozegahara is a basin surrounded by a young volcano Hiuchi-dake (2,346 m), an old volcano Keizuruyama (2,001 m), a lava plateau Ayamedaira (1,969 m), and the Shibutsusan (2,228 m), consisting of granite and serpentinite (Fig. 45). The Rivers Nushiri and Yoppi flow through the basin and the lower course from the confluence of both rivers is called the River Tadami. There are two water falls, Hiraname and Sanjō, near the north end of the basin.

Fig. 45. Geological map of Ozegahara and the surrounding area (After H. KUNO and others).

1, deposit of the Ozegahara basin; 2, Hiuchidake Volcano; 3, Susukemine Volcano; 4, Nikurayama and Sarabuseyama Volcanoes; 5, Ayamedaira Volcano; 6, Keizuruyama andesite; 7, solfatarized rocks of the Tokura Group; 8, granite; 9, serpentinite; 10, Hinoemata Group.

This peat bog is famous for the abundance of the bog flora and has many interesting problems related to the phytogeography. H. Hara and M. Mizushima have mentioned the speciality of the flora of this bog as follows: "The Ozegahara moor....is very rich in northern elements which are commonly found in peat bogs in more boreal regions. The total number of vascular plants growing in the moor attains about 140 species,....Among them are found such species which show striking discontinuous distribution in Japan as *Drosera anglica*, *Myrica gale* var. *tomentosa*, *Scheuchzeria palustris*, *Nuphar pumilum*, *Triglochia palustre*, *Oxycoccus microcarpus*, *Trientalis europaea* var. *arctica*, *Hippuris vulgaris*, *Lysimachia thyrsiflora*, *Utricularia intemedia*, *Epilobium palustre*, *Viola kurilensis*, *Iris setosa*, *Sparganium glomeratum* var. *angstifolium*, *Lycopodium inundatum*, etc. Those species had apparently much wider and continuous distribution than now at least in the last ice-age, and in the postglacial age, the areas of those boreal plants in the ice-age were much reduced in Japan, surviving only very isolated localities in the mountain districts." It is also valuable for researchers that some of the microreliefs which are peculiar to *Sphagnum* bogs are found there.

2. Outline of the Basin.

The basin is divided into two parts according to the difference of topographic features (Fig. 46). The River Nushiri flows on the border of both parts. The eastern part of the basin is covered by the mudflow issuing from the Hiuchidake, and inclines rather gently to northwest. Part of the mudflow penetrates into the valleys of the Keizuruyama and we can see outcrops of this

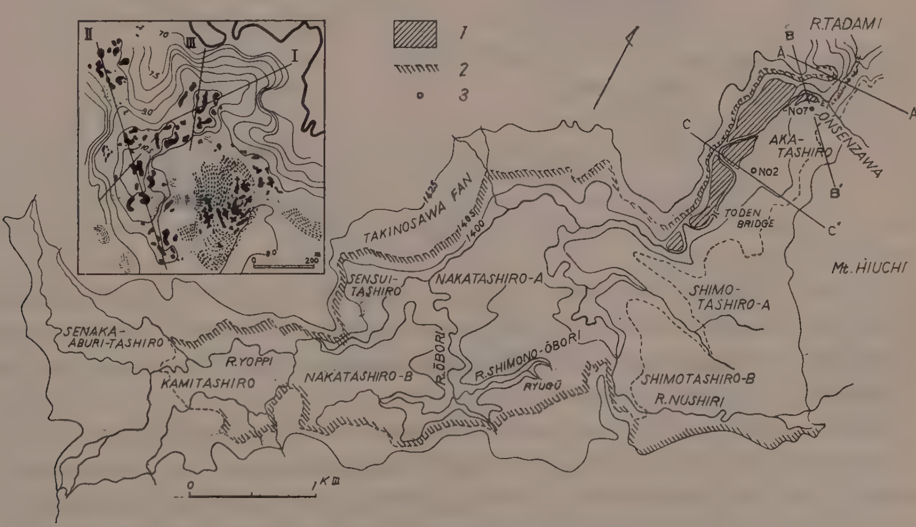

Fig. 46. Geomorphic map of the Ozegahara peat bog and main part of Nakatashiro-A (up to the left).

1, terrace; 2, assumed shore line of Lake Paleo-Oze; 3, boring localities. contour interval in the map of the main part of Nakatashiro-A: 0.5 m.

mudflow along the River Tadami north of the Tōden Bridge. The course of the River Nushiri turns to the west in the basin, having been affected by the mudflow. We call Shimotashiro the area between the River Tadami and the Nushiri, and this area is divided into two parts, A and B, with the River Rokubē.

The River Rokubē is one of the rivulets in the basin, but its valley is wide and the gallery forest is big as compared with a scale of the channel It may be explained as follows: The River Rokubē was formerly a main course. Afterwards its upper course was captured by headward erosion of the River Nushiri, which was only one tributary at that time. Consequently the River Rokubē changed to a rivulet in the former valley.

In the eastern part of Shimotashiro-A and Shimotashiro-B we can see peat banks arranged in a contour line and watery patches (Wasserschlencke) between them, whereas ponds are few there (Fig. 47). Such relief-complex as peat banks

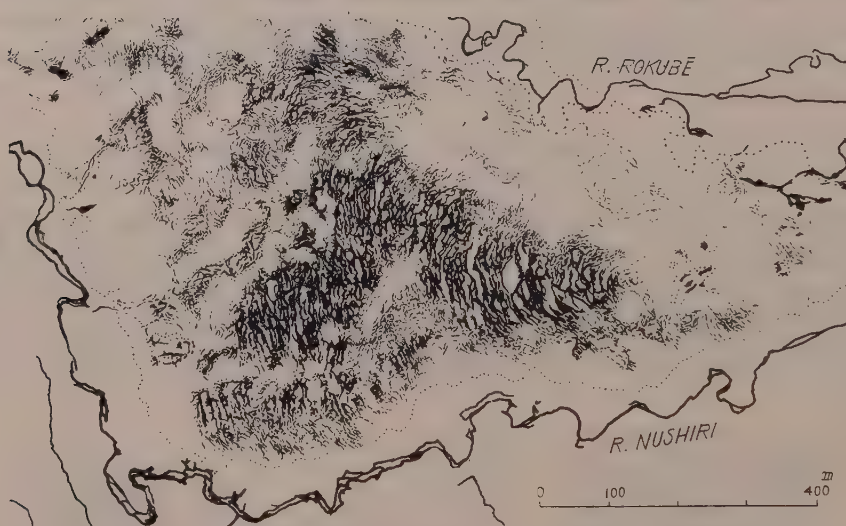

Fig. 47. Peat banks and watery patches of Shimotashiro-A.
black part: watery patches
The slope inclines toward the left. Dotted line shows a boundary of the gallery forest.

and watery patches are called "*Kami-no-tambo* (Gods' paddy field) or *Gaki-no-tambo* (hungry devils' paddy field) in Japan (Fig. 48). Ponds are together in the western half of Shimotashiro-A, and among them the deepest one is 150 cm, but most of them are less than 100 cm deep.

The northest part of Ozegahara is called Akatashiro (red-coloured bog), because bog water there is rich in iron, and bog iron deposits are formed everywhere. This area is, however, morphologically similar to Shimotashiro-A.

A terrace of some metres in relative height has been formed along the River Tadami north of Tōden Cottage, and its surface has been covered by peat.

The western part of Ozegahara is divided into Nakatashiro-A, -B, Kamita-

Fig. 48. Ichôdaira slope moor.

This peat bog is formed on the lava plateau of the Taisetsu Volcanic Group, Hokkaido. Peat banks and watery patches (black) are well developed. An arrowhead shows the direction of the slope.

shiro, Sensui-tashiro, and Senaka-aburi-tashiro. Nakatashiro is at the central part of the basin.

Several alluvial fans fringe the foot of Mt. Ayamedaira. Running water on these fans almost disappear under the ground near the margin of the fans. Today the peat bog is extending over the fans. The water which seeped under the ground flows out again from funnels, so-called *Ryūgū* (dragon palace), and waters stagnating around the funnels form *Comarum* swamp.

Nakatashiro-A area shows the typical features of a high moor. A large swell is seen in the center of this area. The feature of the swell is rather complicated. It is considered that this swell is a complex of several watch-glass-like domes. A relative height between the top of the swell and the marginal swamp is 3.5 m maximum. Deep ponds are assembled on the top of the swell. Peat banks, watery patches and shallow ponds whose *shore development* is large, lie in the area between swell and swamp around *Ryūgū*. The slope of the swell is rather gentle, but rather steep in some places. The gradient of the slope of such swell reaches 15 degree (26.8%) according to K. von Bülow, and 0.3 to 7%, sometimes 32% in Southern Finland according to L. Aario. This amount does not exceed 10% in Nakatashiro-A. The width of the marginal slope in Nakatashiro-A exceeds 30 m, while its amount does not exceed 30 m in Southern Finland. Part of the marginal slope along the River Nushiri in Nakatashiro-A has been eroded by the river, and the former channel is found under

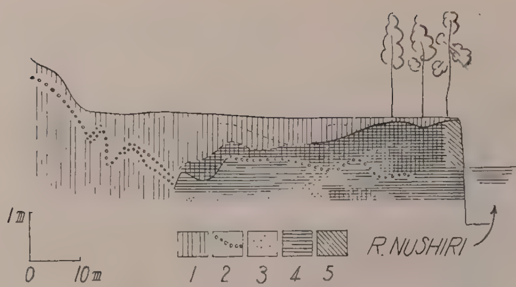

Fig. 49. Section of the marginal part of Nakatashiro-A through the old meander-cliff of the River Nushiri.

1, peat; 2, pumice; 3, sand; 4, silt; 5, loam.

the marginal swamp in front of the cliff in question (Fig. 49). Part of the cliff has been covered by *Osmunda* peat (Fig. 50). As shown in Fig. 49, the fluvial deposits are nearly confined in an extention of the marginal swamp. To accumulate peat in such a marginal swamp means that the river course has been fixed.

Nakatashiro-B is different from Nakatashiro-A in these respects, that the figure of the ponds is irregular, and the depth is rather shallow. It is a characteristic that the main axes of the ponds in the western half of this area are at right angles or slightly oblique to the direction of the River Kami-no-Ōbori. Dome features are not well developed in this area.

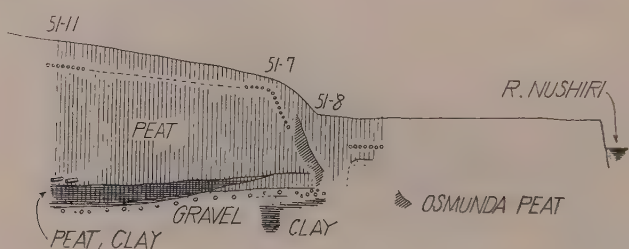

Fig. 50. Section of the marginal part of Nakatashiro-A.

3. Micro-reliefs in Sphagnum Peat Bog.

i. Hummocks and peat banks.

The relative height of the hummocks in Ozegahara is 20 cm more or less, but that of *Sphagnum* hummocks in Hokkaido reaches 30 to 50 cm. Peat banks have several metres of width and 20 cm more or less of relative height, and are arranged in contour-line. The building process of hummocks and peat banks is not yet made completely clear. According to one of the former theories, such features have been considered to be formed by the initial unevenness of the creeping of the peat layer, frost action, and so on. Another opinion is that such unevenness as thickets and hollows among thickets affects the growth of plants there. According to this opinion, it is not necessary to move a peat layer itself. The third is a compromise of the above mentioned theories. We can see *Sphagnum* hummocks having 30 to 50 cm in relative height everywhere in the southeastern Hokkaido. According to the author's observation in the Kushiro plain the volcanic ash layer lying more or less 30 cm under the bog surface around the hummock is not dislocated at all under the hummock. The peat consisting of the hummock is very loose. This fact shows hummocks can

be formed without dislocation of the peat layer. It seems that the formation of peat banks is restricted on the slope, while hummocks are found on the level part of a high moor.

The peat banks in Ozegahara are remarkably developed at Shimotashiro, especially the eastern half of Shimotashiro-B, the area between swell and swamp around *Ryūgū* in Nakatashiro-A, and the area extending from the western part of Nakatashiro-B to Kamitashiro, and all of them are slightly inclined. Physiognomically *Sphagnum* sp. and *Rhyncospora alba* predominate in these areas. We cannot accurately determine the gradient of the slopes, because we have no results of precise topographic survey. It may, however, be considered their values are less than 0.001 at Nakatashiro-A, and about 0.01 at Shimotashiro-B. Notwithstanding that Shimotashiro area wholly inclines to the northwest, the formation of peat banks is restricted in a part of the slope. This fact shows that the gradient of the slope plays an important part in forming banks. Hummocks are formed in the area where physiognomically *Rhynchospora alba* and *Moliniopsis japonica* predominate. That is, the difference between peat bank and hummock is shown not only in feature, but also in vegetation.

Why the difference of vegetation at both areas occurred may be based on the fact that inclination of the bog surface rules relations between plant and water. The author infers that hummocks and peat banks are formed by the same process. K. E. Ivanov has explained the forming process as follows: Values of inclination of the bog surface developing peat bank-hollow complex are fallen in a range from 0.0009 to 0.0004, and peat banks can be formed neither in larger values nor smaller ones than the abovementioned range. But these values are more or less different according to locality, for example, 0.0031–0.0080 in Pri-Angara District. The ground water level of the peat bank forming area is 9–16 cm under the surface in most cases. It is necessary that small shallow hollows or small mounds exist initially. But it may be possible to assume the difference of compactness of surface peat horizon for such unevenness. In such cases an unequal flow of water occurs in a living horizon of vegetation. Stream lines of flowing water are dense at initial hollows or loose parts of the living horizon, while at both sides of each hollow or loose mat stream lines are apart from each other. For this reason growth of hydrophytes in hollows is more vigorous than that on both sides of hollows, and at last hollows are filled with peat. Consequently, both sides of initial hollows change reversely to secondary hollows, then by the same manner the secondary hollows change to mounds, and these mounds link up with the mounds grown from the initial hollows. Thus in this way the mounds linked side by side extend in a direction crossing the stream lines. If there is no hollow but a mound initially, as intervals of the stream lines become narrower at both sides of a mound, these parts change to mounds by growth of hydrophytes, and the new mounds link up side by side with the old one.

The reason that the formation of peat banks is limited within a certain range of inclination has been explained by Ivanov as follows: The mean level of the ground water in a place where the gradient of the slope ranges from

0.004 to 0.017 is 35 cm under the general surface of a peat bog, and 20 cm under the bottom of a hollow, and this level never rises above the bottom of the hollow, even in the flood season of the spring. In a place where the gradient of the slope ranges from 0.004 to 0.0009 the mean level of ground water fluctuates up and down through the bottom of the hollow, and the spring maximum level lies always above the bottom of the hollow. In an area having a gradient of less than 0.0007 or 0.0006 the maximum level lies always above the bottom of the hollow, and generally so high that water covers the whole surface of the peat bog. In the first case water percolates through the living horizon, but in the third case the percolating of water can not occur. Only in the second case water flows in the living horizon, and its flow directly controls the growth of plants.

In Nakatashiro the ground water level in summer is 150 cm under the ground surface at places where *Moliniopsis japonica* predominates, and 4 cm under the ground surface at places where *Rhyncospora alba* predominates. The ground water level in Shimotashiro-B is similar to that in Nakatashiro, and the gradient of the area developing peat banks in Shimotashiro-B is much larger than IVANOV's values. If IVANOV's explanation is correct, in the area showing such a large gradient the origin of water flowing in the living horizon during the vegetative period should be sought in springs. The data are, however, too scanty to discuss the forming process of the peat bank. Further discussion will be given at some later opportunity.

ii. Ponds.

In Ozegahara the most remarkable micro-relief is ponds (Fig. 51). The

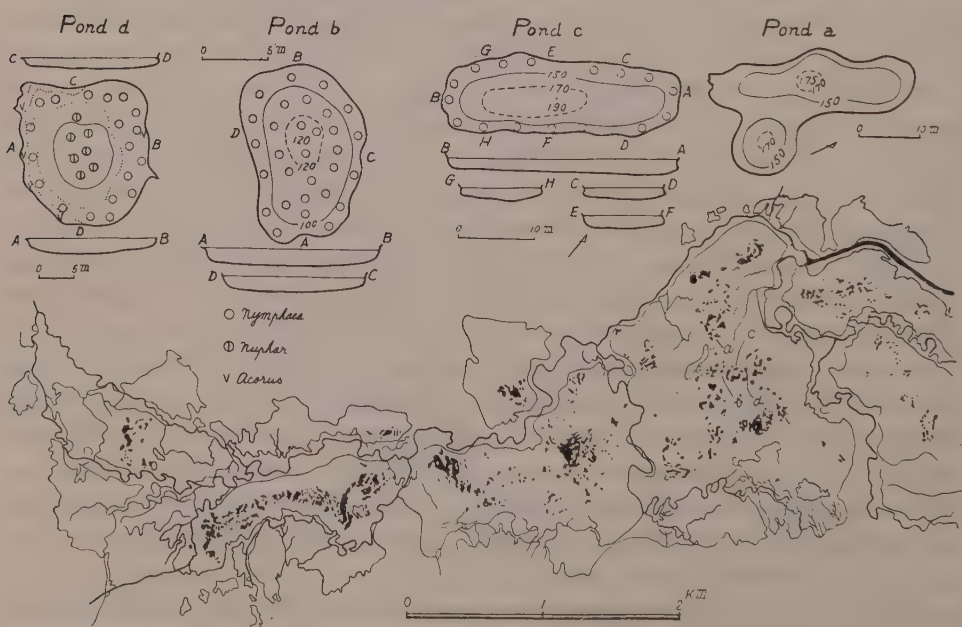

Fig. 51. Distribution of the ponds and morphology of some ponds of Nakatashiro-A. depths in centimetres.

number of ponds which have the depth of more than 50 cm each in this bog reaches about 330. The common morphological features of the pond basin noticable in every pond are as follows: i) The shore is nearly vertical, or overhanging. ii) The deepest point is nearly at the center of the bottom of a basin. A feature of the bottom of a circle-shaped basin in watch-glass-like. A comma-shaped basin has one or several sub-basins, and the deepest point of each sub-basin is also at the center of each sub-basin.

Ponds whose value of the shore development is small are relatively deep in many cases. Notwithstanding that in some comma-shaped ponds the value of the shore development is large, their depths are rather deep. It is considered that such ponds are formed to connect with each other. The depth of such ponds is relatively shallow near the narrowest part of the pond. We can often see islets at similar parts. Ponds having large values of the shore development are assembled in Nakatashiro-A, -B and so on. The variation of depths of the ponds in each area is as follows:

Kamitashiro; 220 cm maximum, 70–140 cm in most cases.
Nakatashiro-B; 170 cm maximum, 100–150 cm in most cases.
Nakatashiro-A; 330 cm maximum, 150 cm< in most cases.
Shimotashiro-A; 140 cm maximum, 50 cm± in most cases.

Though there are many investigations concerning the origin of the ponds, it has not yet been made clear enough. K. von Bülow has summarized the former theories as follows:

1. In the *Verlandung*, part of the initial body of water remains without being completely filled by peat.
2. Water stands in hollows among *Sphagnum* cushions. The space of such a pool is gradually increased by waves and frost actions against the shore.
3. Water stands in a hollow formed by the spouting of *Moorgas* from the peat deposit.
4. watery patch is the initial form.
5. Water stands in a hollow which has been formed by lightning.

Many investigators have supported the fourth theory. Y. Yoshii has investigated the forming process of step bog lakes at the *Gehängemoor* in the Volcano Hakkōda, Northern Honshū, and explained the forming process as follows: On the base of the peat layer changing points of inclination exist there, and springs issue from these points. *Sphagnum* forms a cushion to grow vigorously at these points owing to spring water. Water flow is prevented by the *Sphagnum* cushions, and water stands at the upside of each cushion, thus banks are formed. S. Hori has got the same result at the Volcano Naeba, Central Honshū. At any rate, according to the above-mentioned explanation it is necessary that there should be as many changing points of inclination or steps as the number of the ponds. Neither investigator, however, has pointed out anything on the formation of the relief of the base. At the Ayamedaira peat bog the ponds are situated only in a gently inclined part of the slope (gradient: 0.02) (Fig. 52). We can understand that the inclination of the base of the peat

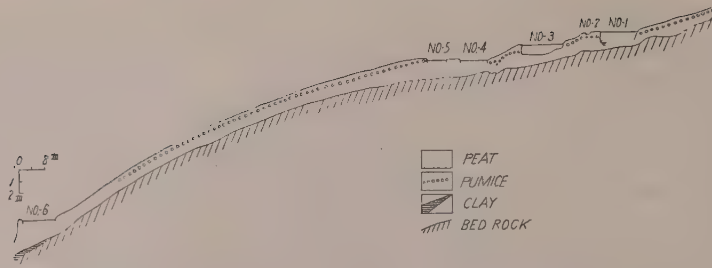

Fig. 52. N–S section through the Ayamedaira peat bog.

layer at that part is nearly parallel with the surface of the peat layer. That is, it may safely be said that the origin of ponds is related to the relief of the base as Yoshii and others say. In this case it is a question why such steps are formed on the base. Such steps might have been formed by frost action.

The ponds in Ozegahara are divided into two groups according to the type of arrangement; irregularly arranged ones and regularly arranged ones. The ponds of the former group have simple outlines and are deep, while those of the latter have rugged outlines and are shallow.

In Nakatashiro-A the first group is situated in the top of the swell. Any

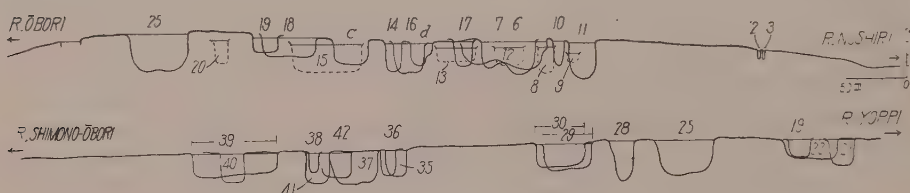

Fig. 53. Profiles of the ponds on the swell of Nakatashiro–A. Localities of the profiles are shown in Fig. 46. upper: I, lower: II.

profile of pond basins is nearly kettle-shaped (Fig. 53). The rate of accumulation of the bottom deposit of the pond is about half or a third of the rate of the accumulation of the peat according to the observations of the shallow ponds. If those values can be applied in every case, it is possible to say that the formation of the deep ponds approximately started from the base of the peat layer. In most cases the ponds on the swell have an axis extending from the north to the south. Some of them are U-shaped, but the circle-shaped ones are very few. If the ponds on the swell have developed from watery patches, their arrangement should be regular to some extent. The author considers these pounds as relics of ox-bow lakes which were formed at the early stage of the peat bog development. Bülow has pointed out that a long axis of ponds approximately coincides with the prevailing wind direction, because the leeward shore of ponds is eroded by waves; conversely the windward one protrudes on the water. Ozegahara is one of the heaviest snow areas in Japan (maximum depth of snow cover: 3–4 m). In winter snow jams are formed on the surface of the ponds, and they move up any down and erode the shore of the ponds. Ice-sheets

floating on the ponds in spring are moved by wind and may erode the shore. Such action may be stronger than the erosion action of floating islets in summer. If such action took place the direction of the prevailing wind in winter or spring at that time would be north or south. Today the direction of wind during the term from March to May is not constant. Consequently it is difficult to say that the north or south wind predominates there. Though, even today, the data concerning the wind direction in the Oze District are not complete. If the direction of wind at that time were similar to that of today, the orientation of the ponds on the swell cannot be explained by the wind erosion only. Today it may be reasonable to consider those ponds as relics of the old ox-bow lakes. A group of the ponds situated in a marginal plain in the south-western part of Nakatashiro-A morphologically belongs to the first group. These ponds are generally a little shallower than those on the swell, but their arrangement is somewhat regular. This group may also be the relics of the old ox-bow lakes.

The second group has a depth of 50 to 100 cm in most cases. The origin of this group is explained by Bülow's forth theory. When water begins to stand constantly in patches, the growth of plants in the patches ceases, and the growth of the border of the patches continues unilaterally. As above mentioned, the border is destroyed by wave action and so on, and fragments of hummocks and peat banks remain in the pond. Such fragments are called fixed floating-islets. K. Yoshioka has the same opinion. V. Auer says when the growth of a peat bog ceases, the surface of the bog gets heavy frost action and water stands there. K. Yoshioka has observed such a phenomenon in Nakatashiro-B.

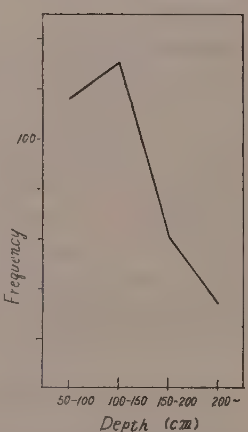

Fig. 54. Relationship between number and depth of the ponds in the Ozegahara peat bog.

When we investigate a distribution of the frequency of the depth, we can divide the depth of the ponds into four classes of 50–100, 100–150, 150–200, and more than 200 cm (Fig. 54). We can understand the ponds with a depth of 100 cm to 150 cm are the most abundant, and those with a depth of 50 cm to 100 cm follow. If the rate of accumulation of the bottom deposits is a half of that of the peat, the initial levels of the bottom of the ponds lie at 200–300 cm and 100–200 cm under the surface. The decomposition grade of peat samples which were taken from the pit on the swell of Nakatashiro-A is shown in Fig. 62. The well decomposed horizons lie at each level of more than 380 cm, 220–300 cm, 130–170 cm, and 0–100 cm under the surface. It is interesting that the initial levels of the bottoms of the ponds correspond closely to the well decomposed horizons. This fact shows that the decomposition of peat is closely related to the development of the ponds. Because water on the surface of a peat bog penetrates with difficulty into the well decomposed

peat, watery patches may easily be formed.

4. Geology of the Superficial Deposits

The thickness of the peat layer of Ozegahara is not over 500 cm in most places. The sequence of the deposit at the pit on the swell of Nakatashiro-A is shown in Fig. 62. In this column we can see the *Sphagnum* thin horizons at each level of 0 cm, 140 cm, 180 cm, 205 cm, 265 cm, and 360 cm under the surface.

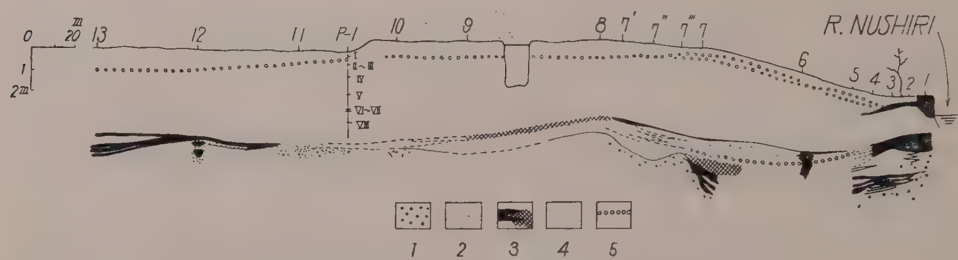

Fig. 55. The section III through Nakatashiro-A.

1, gravel. 4, peat.
2, sand. 5, pumice.
3, silt, clay and organic clay.

As shown in Fig. 55 redish brown loam is deposited along the Nushiri, and is covered by the alternating deposits consisting of peat, organic clay, clay, sand, and gravel.

Considering sand and gravel beds as a base of the peat layer we can find out an old channel at the points of Nos. 5, 6 and 7. The surface of the base from No. 1 to No. 8 is not even. Judging by the feature of the basal deposit and by the heights seen at point No. 8 and at points No. 1 to No. 5 is regarded as buried natural levees. From those facts it is clear that Ozegahara has a characteristic of *Flussmarschenmoor.* The fluvial deposits near the river bed played an important part in raising the surface of the peat bog since the beginning of the accumulation of the peat. We can also see here the phenomenon of *the settling of river courses.*

5. On the Volcanic Ejecta in the Peat Deposit.

We can see eight layers of volcanic ejecta in the peat deposit of the locality P-1 at Nakatashiro-A. Among them the most remarkable layers are the second one and the third one, at each level of 44 cm and 46 cm under the surface. Both layers are composed of pumice having grain from 2 to 4 mm in diameter. The depth of both range from 30 cm to 150 cm all over the basin. Especially the depth of the first layer is 20 cm at the marginal slope, while it appears at the depth of 200 cm at the marginal swamp. Every layer of the volcanic ejecta can be seen most clearly after air drying of the peat. As shown in Fig. 56 the fluctuation of the depth becomes greater near the changing point of the inclination of the slope. All volcanic ejecta above-mentioned are regarded as eolian

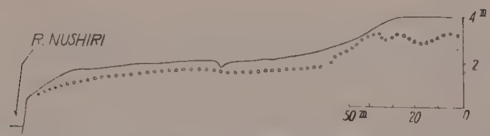

Fig. 56. Section of the marginal part of Shimotashiro-B.

deposits.

In the surroundings of Ozegahara there are one or two pumice layers which lie in a depth of about 40 cm at the bogs and about 20 cm at the other areas. At the Ayamedaira peat bog a depth of such a pumice layer does not fluctuate remarkably as shown Fig. 52. The author considers that such a pumice layer can be correlated with the second or third one in Ozegahara, judging from the grain-size of the pumice, the thickness of the layer and the features of the deposition.

M. Harada has investigated the origin of the Kantō Volcanic Ashes (so-called Kantō Loam) which are extensively distributed in Kantō District. Relating to this study, he has traced the origin of the pumice beds distributed in Northern Kantō, and has assumed the distribution of the pumice bed which is the thickest at the foot of the Futatsudrke, one of the Haruna Volcanoes (Fig. 57). He has called this ejecta Ikaho Pumice Bed. This pumice chiefly consists of hornblende, hypersthene, and augite (very little), and its composition coincides with that of the base rock of the Futatsudake. The author verified Harada's observations along the River Katashina, a tributary of the Tone. According to the microscopic investigation the mineral components of the pumice distributed in this valley is plagioclase, green hornblende, augite, and hypersthene as a phenocryst. This composition is the same as that of the sample collected from the locality of P-1 in Ozegahra. The Hiuchi, Nantai, Harunn, Akagi and Asama, which are situated in the surroundings of Ozegahara, ejected pumice. Comparing the mineral components of the volcanic rocks consisting of these volcanoes with those of the pumice in question, the pumice in question is regarded as the ejecta of the Haruna. The Ikaho Pumice Bed has covered a burial mound lying on the right bank of the River Tone near Shikishima. According to K. Ozaki, Gumma University, the Burial mound period in Northern Kantō closed about the 7th century. Eruption of the Futatsudake was accompanied by quite a big earthquake, and consequently the western stone walls of the burial mound covered with the Ikaho Pumice were destroyed by the shock

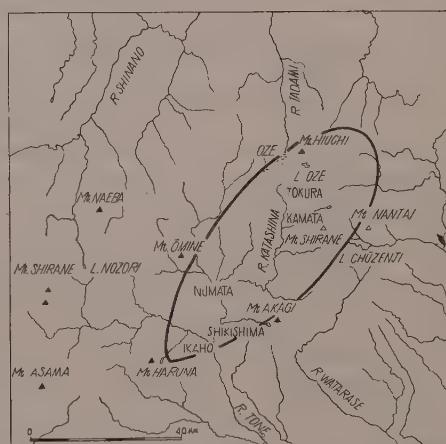

Fig. 57. Map showing the distribution of the Ikaho Pumice (After M. Harada).

of the earthquake. Therefore the eruption of Ikaho Pumice occurred during the Burial mound period, probably about 1,300 years ago.

As the VI and VII volcanic ashes are both characterized by brown or green hornblende, both of them are regarded as the ejecta of the Nantai. Their eruption time is not yet determined accurately, but it is estimated at 3,600 or 4,000 years ago, as the rate of accumulation of peat is 0.7 or 0.8 mm per year in this basin.

6. Geomorphic Development of the Ozegahara Basin.

The deposits underlying the peat layer crop out along the valley of the Tadami north of the Tōden Bridge. Especially along the rivulet running from the Ozegahara Spring we can see alternating layers consisting of organic clay, sand, and volcanic detritus. The alternating layers are covered with mud-flow deposit more than 20 m in thickness. The Tadami entrenches in the lava of the Hiuchidake north of the Rivulet Onsen. The bog iron ore can be seen not only in the recent peat deposit, but also in the terrace deposit near the Rivulet Onsen. According to the boring data taken from several points at Akatashiro, the base rock of this basin is the weathered granite, and underlies the lava from the Hiuchidake of more than 50 m in thickness (Fig. 58). The lava is covered with a clay deposit of 13 m in thickness at the boring locality No. 7. The upper part of this clay deposit is correlated with the alternating layers at the Rivulet Onsen. The mudflow deposit covering those deposits can be traced up to the Tōden Bridge and forms the base of Shimotashiro. As at the Hiraname waterfall the lava cannot be seen in the valley slope of the left bank of the Tadami, it is sure that the Tadami formerly ran east of the present course. It was shifted to the west by lavaflows, and finally the valley was dammed by the lavaflows, and a lake was formed. The author calls it *Lake Paleo-Oze*. The last lava which flowed down at the north of the Rivulet Onsen remarkably raised the water level of the lake. Before the lake was filled up completely, the lava at the exit of the lake was cut down and the water level of the lake fell about 40 metres, and the greater part of the lake was dried up. At the same time a part of the bottom deposits was washed away by running water. Near the Rivulet Onsen the alternating layers consisting of organic clay, sand, and gravel were formed. Successively

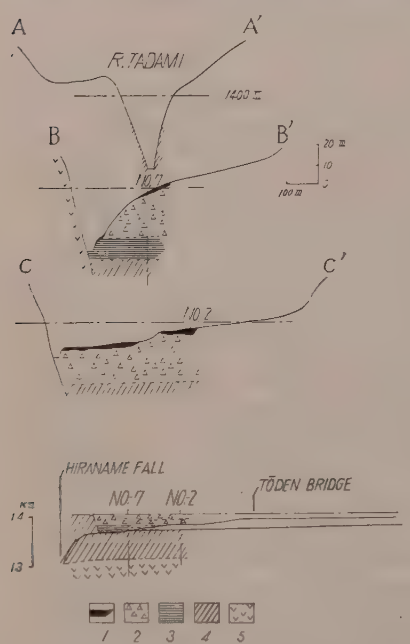

Fig. 58. Cross and longitudinal sections of the River Tadami.

1, peat; 2, mudflow deposit; 3, clay, organic clay, sand and gravel; 4, lava; 5, granite.

these deposits were covered by the mudflow. It is considered that a lake was formed again by this mudflow in Nakatashiro and Kamitashiro. This lake was, however, filled up before long. After the course of the rivers on the peat bog settled in the recent position, peat began to accumulate in the backswamps. Especially, in Shimotashiro and Akatashiro the initial peat bogs were formed around springs.

The age of the timber fragment of *Fraxinus* buried at 4.2 m under the surface has been determined to be 5,678±700 years by the carbon-14 dating method. The decomposed peat layer of 1 m in thickness lies under this horizon. If we estimate the age of this peat layer to be 1,500 years, the beginning of the accumulation of the peat would go back to 6,500 or 8,000 years ago. In Nakatashiro-A the growth of the peat bog has reached the last stage. The age of the organic clay layers at the Rivulet Onsen must be estimated by adding thousands of years to the age of the recent peat layer, at least 6,500 or 8,000 years. During these thousands of years such events as the formation of the mudflow deposit, the filling-up of Nakatashiro and Kamitashiro, and deepening of the river bed occurred.

VIII. Paleogeography of Northern Japan During Holocene Epoch

1. Change of the Sea Level during the Holocene Epoch.

We have not yet got any conclusion to the problem concerning the position of the sea level at the time when the transgression of the Holocene epoch began. The amount of the falling of the sea level during the last glacial age is estimated by the western investigators, and it is considered to be 80 to 100 m by most of them. A. Sugimura has pointed out that the base of the deposits belonging to the Yūrakuchōan and Numian stages in the Tokyo Bay is correlated to the flat surface lying at the depth of 85 m near its mouth, and he has considered that an extension of this surface continues to the bottom surface of the buried valleys lying below the lowland of Tokyo. S. Kaizuka has regarded the submarine flat surface lying at the depth of 80 to 100 m along the southern coast of Kantō District as an abrasion platform which was during a time when the sea level was lower than the present one, and having investigated a correlation between this platform and the subaerials geomorphic surfaces or buried geomorphic surfaces found in Kantō District, he has reached the same conclusion as Sugimura's. Moreover, he has considered ten thousands of years were necessary for the formation of this platform, as a result of the calculation based on an assumption that the flat surface lying at the depth of 20 m less than is an abrasion platform made during the past few thousands years. Meanwhile, T. Yoshikawa has recognized the continental shelf around the Japan Islands is dislocated by crustal movement, and concluded as follows: The subaerial erosion surface made during a time from the end of the Tertiary to the early Pleistocene submerged afterward and was covered with remarkably thick sediments. The continental shelf around the Japan Islands was formed in such a manner. According to his view the low sea levels during the glacial

ages only affected slightly this shelf. He has opposed the theories of SUGIMURA and others, and has mentioned it is not right that we estimate an amount of the change of the sea level due to the glacial eustasy only by such a topography. H. ISEKI has considered the remarkable gravel beds which are found below the alluvial plains in Japan everywhere as fanglomerates which were formed when the sea level was low during the Würm glacial age and the late-glacial age. He has concluded that judging from these fanglomerates the sea level at that time was between the surface of the buried fan lying at the depth of 50 to 80 m and the flat sea bottom lying at the depth of 100 to 120 m. While ISEKI has considered these gravel beds as those of the earliest Holocene, the author considers these beds were formed during the falling of the sea level, that is, these are of the uppermost Pleistocene. These are unconformably covered with the Holocene deposits. Three other investigators' opinions besides YOSHIKAWA's nearly come to an agreement. That is, the sea level is controlled by the building and wasting away of the ice sheets and the amount of falling of the sea level 80 to 100 m.

The author has already mentioned that the humus beds regarded as the deposit directly before the transgression at each locality lie below the base of the Holocene in the lowland of Tokyo. These humus beds are found in Japan everywhere. In Tokyo the maximum depth of the humus beds is 43 m below sea level. The deposit regarded as basal peat bed in the Sarobetsu lowland also lies at the depth of 26 m below sea level. According to such deposit as lies at the base of the Holocene formations and indicates the level of the past geomorphic surface, it may be said that the amount of falling of the sea level does not exceed 40 m under the present shore line. The depth of the humus beds varies. It may be because the buried landforms under the shore line are not even and they would have been influenced by earth movement. According to the author's investigation the crustal movement occurred during a period after the formation of the T-terrace surface till the present. The author has not yet investigated whether the shelf around Hokkaido has been affected by such movement or not. YOSHIKAWA has, however, recognized the displacement by crustal movement connected with the shelf around Honshū. The amount of the displacement by crustal movement during the above-mentioned term estimated by the marine terraces in Hokkaido reaches 30 m, especially 70 m at Osatsu. If the absolute amount of falling of the sea level is 80 to 100 m, the amount of the displacement of 30 m cannot possibly be negligible. Consequently the amount of falling of the sea level must be taken as a relative one. Today we cannot yet take the absolute amount of falling of the sea level at the maximum stage of the Würm glacial age. Consequently we cannot but say the sea level at the time during the transgression was at the depth of 40 m or less than that just under the present shore line.

There are many investigations on the shore line at the maximum time of the transgression of the Holocene epoch. R. TŌKI, a founder of the geomorphology of micro-relief in Japan, carried on an epoch-making work by which he has decided the old shore line by distribution of shell mounds situated in

the Kantō Plain. Tōki has pointed out that the front of the transgressive sea passed through the position of the 10 metres-contour line marked on the present topographic map at least once. Many investigators have supported his theory. The results of boring surveys in the territory in question have also supported the propriety of this theory. An old shore line is decided partly by deposits, and partly various landforms developed only at the shore line. The author has mentioned a beach ridge is the most adequate as an indicator of the position of the shore line. As a raised shore line is covered with deposits lated in many cases, a true elevation of the shore line is commonly lower than a value that can know from a topographic map. The elevation of the shore line at the maximum level of the transgression of the Holocene epoch in Northern Japan is 6.5 m at the coast of the Sarobetsu lowland, 5 m at the Kushiro plain, 5 m at the coast of the Ishikari Plain, 7 to 9 m at the lowland of Tokyo, 6 m or more than it at the Minuma valley, and 7 to 10 m at the Kujūkuri plain.

Iseki has estimated the elevation 3 to 5 m above sea level everywhere in Japan. T. Nakano has pointed out this elevation reaches as far as 20 to 25 m above sea level at the southern part of the Bōsō Peninsula. A. Sugimura and Y. Naruse have made it clear that between the heights (y) of the raised beach and the amounts (x) of upheaval accompanied by the Great Kantō Earthquake at each locality the relationship of $y=6+11x$ holds good. The basis of their thought is an idea of *the inherent intensity of upheaval*, that is, this intensity is proportional to the amount of upheaval accompanied by an earthquake. 11x and 6 in the above mentioned equation represent the amount of seismic upheaval at each locality after the transgression of the Holocene reached the maximum level, and the amount of non-seismic upheaval, namely the amount of glacial eustatic rise of the sea level is measured from the present sea level. Accordingly the elevation of the maximum raised shore line at the transgression of the Holocene epoch is 6 m above sea level. Though the nature of *the inherent intensity of upheaval* is not yet clear enough, the attempt by Sugimura and Naruse, that has separated the amount of the change of the sea level related with glacial eustasy from the amount of upheaval by their original method, ought to be highly appreciated. The results on the maximum height of the sea level taken by the author, except the Ishikari and Kushiro plains, are larger than those taken by Iseki, rather similar to Sugimura and Naruse's one.

The maximum time of transgression of the Holocene epoch is generally considered the beginning of the early Jōmon period or the end of the earliest Jōmon period according to the position of the shell mounds, kinds of shells, and the typology of the earthen wares contained in the shell mounds. As the age of the Kīzima shell mound of the eariest Jōmon period and the Kamo relics of the early Jomon period are 6,443±350 B.C. and 3,145±400 B.C. respectively, the maximum time of transgression may be between these two values. Peat bogs extended in the former transgression areas must commonly be formed after the regression or around the end of filling of basins. It has, however, been made clear that the oldest peat bogs in these areas was formed 5,000 to 6,000 years ago in the Sarobetsu lowland and the Ishikari Plain. Accordingly

the transgression areas in these two regions should have changed to the land by 3,000 to 4,000 B. C. Therefore the maximum time of the transgression is earlier than it. ISEKI has estimated this maximum time about 3,500 to 3,000 B. C. in Kantō District and about 3,000 to 2,000 B. C. in the Nōbi Plain. SUGIMURA and NARUSE have also estimated this time 5.000 B. C., perhaps 4,000 B. C., judging by the result that the time of the relics of the middle Jōmon period is 4,850±270 years. The author emphasizes the maximum time of the transgression is represented not by one time point, but by a rather long time range. The time when the transgression reached in the maximum level for the first time may be 6,000 to 5,000 B. C., and afterward till 4,000 to 3,000 B. C. the sea level would be nearly stable or become only a little lower.

The rapid transgression in Europe is considered to have occurred after the second Salpausselkä stage when the summer temperature suddenly began to rise. The sea level about 8,000 B. C. was 21 m below sea level in the northwestern coast of Germany after H. SCHÜTTE, more than 55 m below sea level in the same region after T. NILSSON, and 55 m below sea level in England after H. GODWIN. The rate of rising of the sea level is 1.65 m/100 years during the time from 5,500 to 4,000 B. C., 0.5 m/100 years during the time from 4,000 to 2,000 B. C., after Dittmer, and 1 cm/year during the time from 7,000 to 2,000 B. C. in the North Sea after NILSSON, and 23 to 26 cm/100 years and 60 cm/100 years at the first time and the last stage of the same period in the Baltic Sea after TAPFER. Most of the investigators of Japan have understood that the transgression in question occurred rapidly as in Europe. But unexpectedly its proofs have hardly been found in Japan. According to T. ESAKA's investigation, while the shore line in Southern Kantō was in the offing during the earliest Jōmon period, it was situated inland of 50 km far from the present shore line during the time from the end of the earliest Jōmon period to the early Jōmon period. SUGIMURA and NARUSE have considered this result as a proof of the rapid transgression. But as the sea shore easily moves in, if an area is flat, it is not adequate to estimate the speed of transgression by the shifting of a shore line. ISEKI has considered the sea level during the time from the beginning of the earliest Jōmon period to the middle Jōmon period was at 10 to 15 m below sea level, judging from a relationship between the horizons of the shell beds recorded at the boring data and the age of the shell mounds situated near the boring localities. ISEKI has regarded this time as about 4,000 B. C., and the maximum time of the transgression as 3,500 to 2,500 B. C. Now, if the amount of the rise of the sea level during 1,000 years from 4,000 B. C. to 3,000 B. C. had been 15+5=20 m, the rate of the rising would be calculated as 2 cm/years. This value is the greatest among the values that have been taken in Japan. We cannot but expect future investigators to make it clear whether this value can also be taken in the Sarobetsu lowland and the Ishikari Plain, or not. If the regression, however, began at 1,000 B. C. the rate of the fall of the sea level would be 2 mm/year, as the amount of the fall of the sea level from the maximum level to the present one is 5 to 6.5 m. This value is smaller than not only ISEKI's one, but also any values calculated by the European inves-

tigators. Consequently the rate of the rise of the sea level since 8,000 B. C. as the European investigators mentioned is remarkably large compared with the rate of the fall of the sea level, and in this point of view it would be allowed to call *the rapid transgression.*

Most of the Japanese investigators have not so seriously taken up the beginning of the regression as that of the transgression. However, since the earth history of an alluvial plain is one of the important subjects of the lowland studies, the time of the beginning of a regression should be taken up as a problem when the lowland forming processes began. The time near Tokyo has been estimated as 1,100 B. C. judging by shell mounds and remains. According to NAKANO, the regression in the Kujūkuri plain occurred earlier than in the region around the Tokyo Bay, and a minor transgression occurred in the late Jōmon period. The regressions in the Sarobetsu lowland, the Ishikari Plain, and the Kushiro plain took place smoothly without temporary stagnation or minor transgression on the way. But the author considers the falling of the sea level might have ceased temporarily at the elevation of 2 to 3.5 m in the Nakagawa lowland. ISEKI has concluded that at the end of the regression the sea level at that time was at 1 to 2 m below sea level, and the sea level rose again during the period from 1,000 B. C. to A. D. 200. The author has not yet got proofs for verifying this result. It would, however, be possible for him to conclude that there is such a landform as its origin can easily by explained by a minor transgression. If this minor transgression had existed, it should be regarded as an episode or a local phenomenon.

2. Peat Bog Forming Periods.

In Japan the formation of the peat bogs occurred four times during the Holocene epoch. The oldest one is the period of the accumulation of basal peat. The humus beds lying at the base of the Holocene formations would be of this period. The second one is the period from 4,000 to 3,000 B. C. to the present. The third and fourth ones are the periods about 1,000 B. C. and around the Christian era respectively.

According to the results of the pollen analysis we can understand that the formation of peat bogs in the Holocene epoch took place under an environment which was remarkably different from that of the Pleistocene epoch. The author has treated the samples of 13 series—Sarobetsu-Ht, Sarobetsu-Old (−13 m), Sarobetsu-Basal (−26 m), Chikubetsu, Haboro, Tomamae, Shinotsu-Kisen, Kawaminami, Osatsu-Upper, Osatsu-Lower, Azuma, Nakagoya, and Ozegahara-Old (Figs. 59 and 61). The author made use of S. HORI's result on the Ozegahara recent peat (Fig. 62). The peat deposits of the sampling localities of Ht, Shinotsu-Kisen, and Ozegahara-Recent now continue to accumulate. The author analysed some samples collected from Kabutonuma and Kamisarobetsu areas in the Sarobetsu lowland. As Kabutonuma area is surrounded by the forests consisting of the *Alnus* and so on, the pollen spectra are remarkably different from each other, though the sampling localities are close to each other. While,

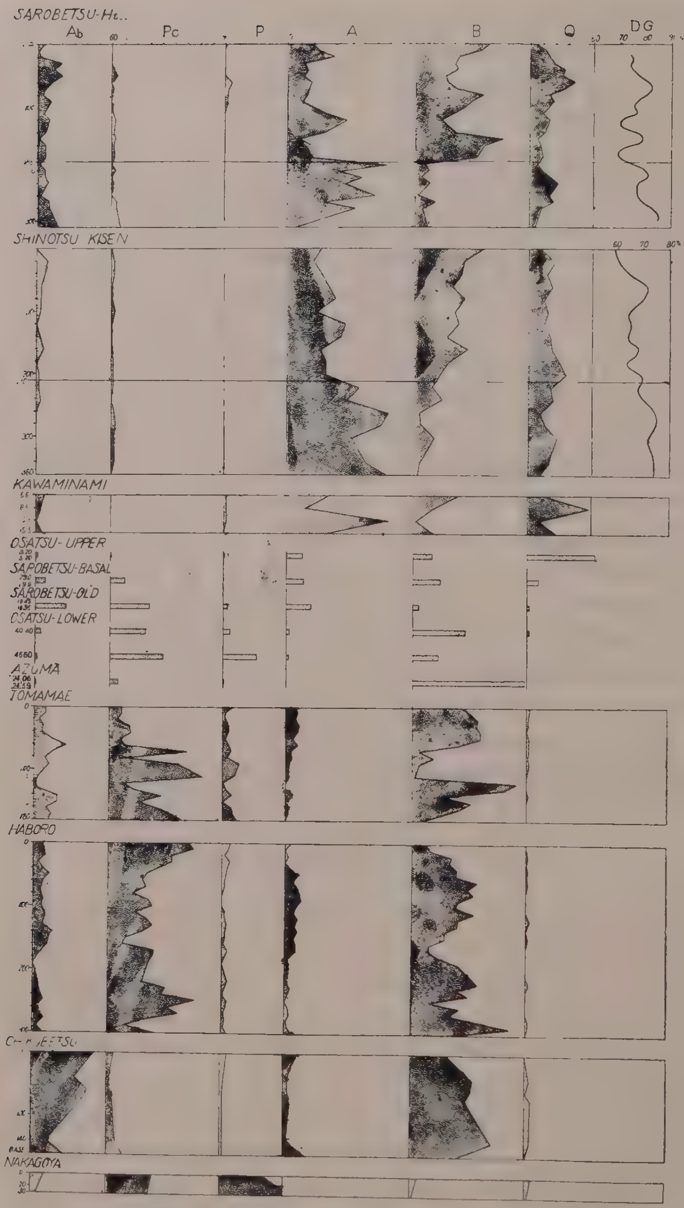

Fig. 59. Pollen diagrams from Hokkaido
Ab, *Abies*; Pc, *Picea*; P, *Pinus*; A, *Alnus*; B, *Betula*; Q, *Quercus*; D. G., decomposition grade.

the pollen diagrams of Ht and No. 66 at the section G in Fig. 11 are very similar, notwithstanding that the distance between these two localities is as far as 4 km (Fig. 60). These results tell us the pollen diagrams of Kabutonuma clearly show the local over-representation. Consequently, the author has taken up the result of Ht as a typical pollen diagram of the Sarobetsu recent peat deposit. The samples of Kawaminami and Osatsu-Upper are collected from the

buried peat layers lying on the marine alluvial deposits. The samples of Sarobetsu-Basal are collected from the already mentioned basal peat layer in the Sarobetsu lowland. The samples of Sarobetsu-Old are collected from the peat layer at the boring locality No. 4 near Ht. This peat layer is considered a member of the buried terrace deposits as showed in the schematic section B of Fig. 14. The samples of Chikubetsu are of the C-terrace deposits, and the samples of Haboro, Tomamae, Osatsu-Lower and Azuma are of the T-terrace deposits. The samples of Nakagoya are stratigraphically referred to the end of the lower Pleistocene or the beginning of the upper Pleistocene. The samples of Ozegahara-Old would be of the early Holocene. The author classified the sample series of Hokkaido into two groups to examine their significance; that is the group A—Ht, Kisen, Kawaminami, Osatsu-Upper, and Sarobetsu-Basal, and the group B—Sarobetsu-Old, Osatsu-Lower, Azuma, Tomamae, Haboro, Chikubetsu, and Nakagoya.

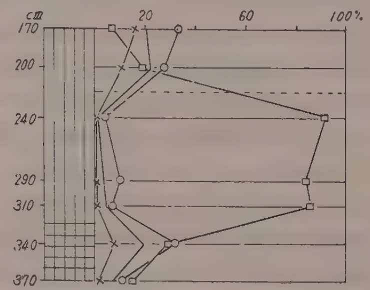

Fig. 60. Pollen diagram of Kamisarobetsu-66. Explanation of the pollen signatures is given in Fig. 61.

a) While the group A is very poor in *Abies*, *Picea*, and *Pinus* and very rich in *Alnus*, *Betula*, and *Quercus* in B group a relation between the former and the latter is the reverse except for *Betula*. According to some investiga tions the relations between the percentage of trees in the surrounding forests and of pollen in the topmost deposits are roughly as follows: *Alnus* and *Betula* are over-represented, *Abies* is slightly under-represented, and *Picea* is nearly adequate. Consequently it is nearly sure that the conifer trees predominated overwhelmingly during the periods of the peat layers belonging to the group B. While *Larix* appears only in the superficial horizon in the group A, it can be found in every horizon in the group B except Osatsu-Lower, Azuma, Chikubetsu and Nakagoya.

b) Seeing only the conifer pollen, the percentages of the *Abies* are generally larger than those of the *Picea*. This relation is regarded as a real representation of the vegetation of each horizon of each locality. This relation is *Abies* < *Picea* in the group B except Chikubetsu.

c) Seeing only the decideous pollen, the *Alnus* and *Quercus* of the group B are very few as compared with of the group A, whereas the *Betula* predominates in both groups. *Betula* forms a secondary forest after a fire. Accordingly as the forest composition also changes by non-climatic accidents, a cause of changes is difficult to be determines by the diagram of only one locality. In this case, however, as the curves of the *Betula* of each diagram in question are roughly similar, a cause of the fluctuation of the curves seems to depend on the climatic conditions. The author expects *Betula* species which was predominant at that time is different in both groups, though it is yet difficult to discriminate epoch species of the *Betula*.

Comparing with each series the following features are pointed out.

a) In Kawaminami *Picea* does not exist, and the percentages of the *Quercus* are larger than those of other series of the group A. Osatsu-Upper is correlated to the second horizon of Kawaminami, judging by predominating *Quercus*.

b) The pollen spectra of Sarobetsu-Basal are between those of both groups.

c) Tomamae series corresponds to the horizons of 40 to 260 cm of Haboro series. Consequently the Tomamae peat layer is compressed to 40 cm in thickness as compared with Haboro.

d) The pollen spectra of Sarobetsu-Old do not coincide exactly with those of Haboro. This discordance seems to be caused by the fact that this sample has not been taken from one horizon of −13 m, but is a mixture of the peat colum of 50 cm in thickness. However, it is also considered that the Sarobetsu-Old peat layer is the deposit of the other stage of the T-terrace forming. In either cases Sarobetsu-Old would de correlated to the Haboro series.

e) The horizon of 40.40 m of Osatsu-Lower is correlated to the horizon of 300 cm of Haboro judging by the following respects: i) The percentages of the *Picea* are larger than those of the *Abies*, ii) the *Betula* dominates, iii) the *Larix* does not exist, and iv) the *Salix* is relatively abundant.

f) Seeing the pollen spectrum of 45.60 m of Osatsu-Lower, this horizon seems to be correlated to Nakagoya so far as *Pinus* concerned. But this is different from Nakagoya concerning that the percentage of *Betula* of Osatsu is considerably larger than that of Nakagoya. Meanwhile, the pollen spectrum of 45.60 m of Osatsu-Lower is similar to that of Haboro on one side, and to that of Nakagoya on the other side, As no series are correlated to this horizon, it is sure that the time of this horizon is older than that of Haboro. Azuma is identified with Tomamae in the horizon of 120 cm. The characteristics of Chikubetsu are as follows: i) The relation between the *Abies* and the *Picea* is the same with the case of the group A, but the percentages of the *Abies* are remarkably large. ii) The percentages of the *Pinus*, *Alnus* and *Betula* are nearly the same as those of the group B. iii) The percentages of *Quercus* are somewhat larger than those of the group B.

g) The characteristic of Nakagoya is the *Pinus* and *Picea* are predominant amongst the tree pollens. In Hokkaido it is considered that the species of *Abies sachalinensis*, and that of *Picea* is *Picea jezoensis*. The relation between *Abies* and *Picea* in the forests is generally Ab>Pc in the lowlands of Hokkaido, and Ab<Pc in the high mountains.

The region where the *Picea* is predominant in the lowland, is Middle Sakhalin north of the line through Uglegorsk and Vostochny. *Larix* does not exist in a natural state in Hokkaido. The *Larix* of B group are regarded as those of *Larix Gmelini*, and the pollens found in the superficial horizon are of *Larix leptolepis* afforested in the recent.

T. YAMAZAKI has classified the climate of Northern Japan in five types as follows: (I) *the climate of the northern part of South Sakhalin* represented by such a forest type as *Picea* is more dominant than *Abies* and there is also *Larix*: (II) *the climate of the southern part of South Sakhalin* represented by such a

forest type as *Picea* is more dominant than *Abies* and *Larix* does not exist; (III) *the Hokkaido climate* represented by such a forest type as *Abies* is more dominant than *Picea* and there is *Picea Glehnii*; (IV) *the climate of the mountain land of Hokkaido* represented by such a forest type as *Picea* is more dominant than *Abies* and there is *Picea Glehnii*; (V) *the climate of the northern part of Honshū* represented by such a forest type as *Abies* is predominant and there is *Fagus*. If this classification can be applied to the present problem, the climate of the period of Kawaminami may be referred to the type III or V, that of the period of Sarobetsu-Old, Haboro, and Nakagoya to the I or IV, and that of the period of Chikubetsu to the type II.

Now it is clear the period of Kawaminami is remarkably different from other periods. In Sarobetsu-Basal the conifer and *Betula* are not so remarkably dominant, no matter that this spectrum is similar to each spectrum of Haboro. Moreover, *Juglans* which is contained a few in Ht, but scaresely exists in Haboro exists as much as 14%. Judging from these facts, the period of Sarobetsu-Basal is considered to refer to the beginning of the Holocene epoch.

The author will successively examine the results concerning on the peat layers of the Holocene.

a) It is clear that the horizon of 3.6 m of Kisen is correlated to that of 2.6 m of Ht. The conifer pollen, is, however, abundant of Ht than of Kisen in any horizon. The peaks of the curve of the *Abies* are at the base and the horizon of 30 to 50 cm at Ht, at the horizon of 20 to 40 cm at Kisen. *Picea* are near the base of Ht, but they are scarecely found at other horizons. Both series are divided into two zones, the upper one and the lower one, based on the behaviors of the *Alnus* and *Betula* curves. The boundary lies at the depth of 185 cm at Ht, 230 cm at No. 66 of Kamisarobetsu, and 210 cm at Kisen.[1] In the upper zone the *Betula* dominates, while in the lower zone the *Alnus* dominates. It is interesting that while in the lower zone of both series the *Betula* and *Quercus* curves are nearly parallel to each other, but the *Alnus* curve is entirely reverse against the former curves, in the upper zone the *Betula* and *Quercus* curves shows a reverse correlation. The same relation is also seen in the diagram of No. 66. These relations may show that the combination of the species between *Betula* and *Quercus* in the upper zone is different from that is in the lower zone.[2]

b) It is known in the lower region of the Amur that *Quercus* was very dominat during a time in the Holocene epoch. M. I. NEISHTADT has pointed out that the percentage of pollen of *Quercus mongolica* changed with a time, namely, it was less than 2% during the earliest Holocene (9,500–12,000

1) This boundary corresponds to the minimum of the percentages of the *Abies* and *Quercus* of Sarobetsu. In Kabutonuma in spite of the great difference of the percentages of the *Alnus* and *Betula* from those of Ht, this minimum part, the boundary of the upper zone and the lower one, is clearly seen in any locality. Its depth is about 300 cm. The difference of the depth of this minimum in each locality seems to depend on that of the decomposition grade of the peat.

2) It is sure that there are more than two kinds of *Quercus* pollen in the samples analysed by the author.

years ago), less than 7% during the early Holocene (7,000–9,500 years ago), 48% in maximum during the middle Holocene (2,500–7,000 years ago), less than 10% at the present. According to M. Kh. MONOSZON, *Quercus mongolica* is distributed only in Maritime Kray, Northeast District of China, Korea, and North Japan. If the *Mongolica* pollens are contained in the sample series of Hokkaido, the peak of the curve of *Quercus* in the Kawaminami would be referred to *the middle Holocene* in Maritime Kray. If this assumption is right, it would have been warmer in the period of Kawaminami than today in the summer half year. It means *the Climatic Optimum* is also recognized in Hokkaido.

c) Between the decomposition grade of peat and pollen spectra in the same sample series there is a definite relation. The horizon where pollen spectra change just correspond to the horizons where decomposition grades change. This fact shows that the factor which influences the soil moisture and the soil temperature as the controlling factors for the decomposition of peat is in common with that which influences the forest in the surroundings. It also shows that the change of the decomposition grade does not depend on the kinds of peat forming plants. This remarkable relation is recognized not only in Ht and Kisen, but also in the other series of Hokkaido and in Ozegahara-Recent. The maximum values in the curve of decomposition grade of Ht are at horizons of 70, 150, 200, and 270 cm, and the minimum values at those of 15 to 60, 130, 170, 220 to 240, and more than 280 cm.

Most of the *Abies* pollens in Ht are considered to have been derived from the Hōtoku upland and the sand dune zone. A close relation, however, exists between the decomposition grade of the peat and percentage of the *Abies* no matter that now the sampling locality and the *Abies* growing area is entirely independent. To explain this relation satisfactorily the author considers climatic change as the environmental condition that is common to both localities. Also the following facts cannot be overlooked as a more unexpected coincidence:

1) The *Alnus* predominates in the lower zones Ht and Kisen.
2) The *Alnus* curves are nearly parallel to those of the decomposition grade.
3) The *Betula* and *Quercus* curves are just reversely related to the *Alnus* curve.

These trends of both series are well correspondent notwithstanding that both localities are very far apart from each other. The cause for such changes of the pollen flora and the decomposition grade cannot be considered except the climatic changes.

Thus we have seen that the remarkable boundary between the upper and and the lower zones in pollen diagrams also appears in the curve of the decomposition grade. The peat deposits of the lower zone are more decomposed than those of the upper zone in Hokkaido. In the period of the lower zone it seems to have been drier than in that of the upper zone, perhaps because of the rising of the summer temperature and the decreasing of the precipitation. The change of the climate from the period of the lower zone to that of the upper one suddenly took place. The behaviors of the pollen curves of the upper zone are

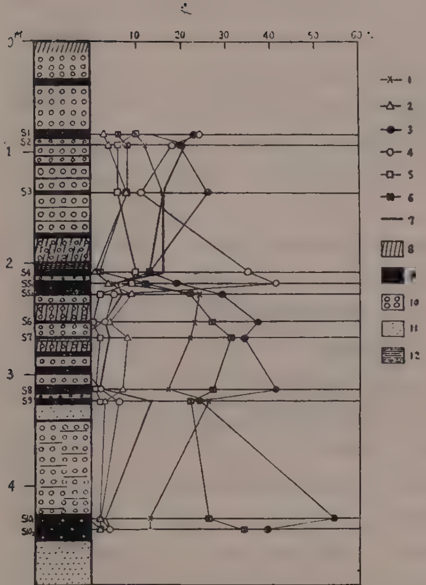

Fig. 61. Columnar section and pollen diagram of the deposits in the final stage of Lake Paleo-Oze.
1, *Abies*; 2, *Picea*; 3, *Pinus*; 4, *Betula*; 5, *Alnus*; 6, *Tsuga*; 7, *Quercus*; 8, humus; 9, organic clay and clayey peat; 10, gravel; 11, sand; 12, clay.

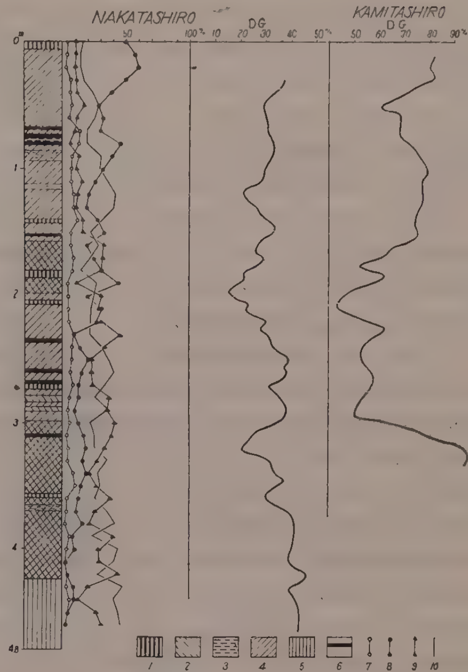

Fig. 62. Pollen diagram of Nakatashiro (After S. Hori) and the curves of the decomposition grade (D. G.) of the peat layers of Nakatashiro and Kamitashiro.
1, *Sphagnum* peat; 2, *Oxycoccus* peat; 3, *Carex* peat; 4, *Moliniopsis* peat; 5, *Phragmites* peat; 6, pumice and volcanic ash; 7, *Betula*; 8, *Pinus*; 9, *Fagus*; 10, *Quercus*.

more complicated than those of the lower zone, but as a relation is partly seen between those curves and the curves of the docomposition grade, the change of the pollen spectra cannot be explained only by the succession. The climate of the beginning of the Holocene epoch in Hokkaido was yet influenced by the Pleistocene climate. But when the transgression began and the front of the sea passed the present shore line, the climate would have nearly been similar to the present one. When the sea level reached the maximum, the climate was drier than that of the present. At that time the I and II sand dune ranges in the Sarobetsu lowland and the Momijiyama sand dune range in the Ishikari Plain developed. The intensive formation of the peat deposit in Hokkaido began about 4,000 to 3,000 B. C. But it was yet under the dry climate then. The summer temperature at that time would have been higher than the present one, if the period of Kawaminami is correlated to part of *the middle Holocene* in Maritime Kray. The climate suddenly became humid around 1,000 to 500 B. C., but became again relatively dry around the Christian era.

Comparing the pollen spectra of Ozegahara-Old with those of Ozegahara-Recent analyzed by Hori, the compositions of both pollen floras are very different (Figs. 61 and 62):

1) Conifer Pollens such as *Abies*, *Picea*, *Pinus*, and *Tsuga* are predominant through all the horizons of Ozegahara-Old, especially in the horizons lower than S5, while in the spectra of Recent such pollens are not dominant except *Pinus*. *Pinus* in Ozegahara-Recent shows large value of 50 to 60% in the superficial horizon. 2) *Fagus* is remarkably dominant in Recent, while in Old it is very scant, less than 3%, moreover, it does not exist in some horizons.

The pollens found in Old are morphologically identified with those in Recent, that is, *Abies; A. Mariesii*, *Picea; P. jezoensis*, *Pinus; P. pumila* and *P. parviflora*, *Tsuga; T. diversifolia*, *Betula; B. Ermnai* and *B. platyphylla*, *Fagus; F. crenata*, and *Quercus; Q. mongolica*.

The slopes surrounding Ozegahara are covered by the *Fagus* forest, and the forest gradually changes to the needle tree one from the elevation of 1,550 m on the western slope of the volcano Hiuchidake. As reflected in such a state, *Fagus* occupies as much as 31% in pollen flora in the superficial horizon of the peat at Nakatashiro. However, according to the pollen diagram made by HORI, in the peat *Fagus* forest was more dominant than the present. The difference of the percentage of the *Fagus* in both spectra cannot be explained by local ecological conditions or accidents. In this case such a climate as being unadequate for the growth of *Fagus* ought to be considered. That is, it would seem most fitting to explain it by the fall of the summer temperature. The surroundings of the Ozegahara basin would have been covered by the needle tree forest because most of pollens fall commonly in the forest. HORI was regarded *Pinus* pollen in Ozegauara-Recent as *P. pumila*. *Pinus* is abundant in the superficial horizon in Ozegahara-Recent. As *Pinus pumila* is distributed in the zone of more than 1,700 m in elevation at the Shibutsu (2,228 m), more than 2,050 m at the Hiuchidake (2,346 m), perhaps the *Pinus* pollen in Ozegahara- Recent is considered to have chiefly derived from the Shibutsu. In the case of *Pinus* pollen, though its percentage is large, *Pinus* forest does not always exist directly in the neighborhood of the sampling locality. However, it is sure that the vertical distribution pattern of the forest shifted down as a whole in the period of Ozegahara-Old and the Ozegahara basin was at least in the needle tree forest. The amount of this vertical displacement is about 200 to 400 m. As the age of the old peat layer in Ozegahara is estimated about 8,000 years $+\alpha$ (α: less than 10,000 years), it is possible to say that at the beginning of the Holocene epoch in Ozegahara it was also colder than in the present.

S. HORI has divided the accumulation time of Ozegahara-Recent into the following five periods by the pollen analysis: 0–20 cm; *Fagus-Pinus* period, 20–300 cm; *Quercus-Fagus* period, 300–380 cm; *Fagus-Quercus-Ulmus* period, 380–400 cm; *Fagus-Quercus-Pterocarya* period, and he has pointed out that it was warmer in the former two period than in the latter two ones.

In Ozegahara the author has got the result as shown in Fig. 62, having analyzed the decomposition grade of the peat from the pit from which HORI collected the samples. In this case there is no relationship between the peat forming plants and the decomposition grade of peat. Excluding the well-decomposed parts of the volcanic ash beds seen up and down the recent peat

layers of Ozegahara is divided into two parts by the ill-decomposed part near the depth of 200 cm. As this ill-decomposed part is also seen at the peat of Kamitashiro, this phenomenon is not local.

Meanwhile, the pollen spectra are as follows:

1) *Pinus* and *Quercus* are dominant in each horizons of the depth of 0 to 155 cm, and the top of the *Pinus* curve corresponds the bottom of *Quercus* curve, and the converse is held good.

3) The percentage of the *Pinus*, *Quercus* and *Fagus* shows nearly the same in the range from 155 to 255 cm in depth.

3) The *Fagus* and *Quercus* are dominant in each horizon more than in the depth of 255 cm, and the same relationship between *Pinus* and *Quercus* is seen.

Namely, the zone from 155 to 225 cm has a transitive characteristic from the lower zone to the upper, and it just corresponds to the ill-decomposed part. If the *Pinus* is *P. pumila*, in the period of the lower zone it would have been warmer than in that of the upper zone, in opposition to Hori's opinion. J. Nakamura has also concluded that the climate in Ozegahara has changed as the following schema: colder period—increase of the warmth—warm period—decrease of the warmth—recent. That the decomposition grade in the lower zone is somewhat larger than in the upper zone seems to prove that in the period of the lower zone it would have been warmer and drier than in that of the upper zone. But the climate became relatively moister in the period of the transitive zone. Also the author considers that even the slight change of the temperature gives an important effect upon the production of the hydrophytes, and the amount of the production may suddenly be increase even by a slight fall of the temperature, and consequently the decomposition grade may relatively have decreased. That time is estimated to have been 1,000 to 500 B. C.

3. Conclusion.

Now the author has unexpectedly got the same results concerning the climate of the Holocene epoch in the lowlands of Hokkaido and the mountain land of Central Honshū. That is, in the beginning of the Holocene epoch it was relatively colder than in at the present. Afterwards the temperature rose, and in about 5,000 B. C. when the transgression was in maximum, the climate was somewhat warmer and drier than in the present. The climate, however, suddenly changed around 1,000 to 500 B. C., and the temperature fell and became cooler and moister. But it did not continue very long. The climate became again drier around the Christian era. The warm period before 1,000 B. C. corresponds to *the Climatic Optimum* in Europe. In Northern Japan the first peat bog forming period began at the beginning of the Holocene epoch, the second at 4,000 to 3,000 B. C. The latter was the period when the *Flussmarschenmoore* (basin moors) were intensively formed in the lowlands of Northern Japan. Thirdly the climate became cooler and moister since 1,000 B. C. The author believes most of the slope peat bogs or watershed peat bogs as the Ayamedaira peat bog occurred in that time. In Ozegahara most of the ponds which devoloped on the peat layer would have occurred in that time. The relics re-

Table 2. Paleogeography of Northern Japan in the Holocene epoch.

					SAROBETSU LOWLAND		ISHIKARI DEPRESSION								
PEAT FORMING PERIOD	ABSOLUTE CHRONOLOGY	DIVISION OF PREHISTORIC AGE	CLIMATE	CHANGE OF SEA LEVEL	SAND DUNE ZONE	PEAT BOG AREAS	SAND DUNE RANGE	PEAT BOG AREAS	KUSHIRO	KEMIGAWA	TOKYO	MINUMA AYASE	NAKAGAWA	KANOGAWA	OZE
	1000	Historic Age		Regression		SAROBETSU PEAT FORMING PERIOD	Formation of Coastal Sand Dune Range		Period of Peat Bogs	Accumulation of Peat	Accumulation of Peat	Accumulation of Peat			PERIOD OF QUERCUS-PINUS
IV		Burial Mound P.	Decreasing Warmth; Dry		Formation of Sand Dune Range III	Accumulation of Peat in Toyosato Area							Change Zone III	Accumulation of peat Yamaki & Mamanoue Relics	Eruption of Mt.Futatsu-dake
	0	Yayoi P.													
III		Jōmon Period: Latest	Moist		Sand Dune Ranges I and II were covered by Vegetation.	Beginning of Accumulation of Peat; Kamisarobetsu Area		Beginning of Accumulation of Peat; Shinotsu; Osatsu Upper Kawaminami						Accumulation of Organic Clay	Begin. of Form. of Peat
	1000			+5			Formation of Momijiyama Sand Dune Range			Canoe, Seeds of Lotus			Change Zone II		Form. of Ayame-daira Peat Bog; PERIOD OF QUERCUS-FAGUS
	2000	Late	Warm and Dry	Stable Stage	Formation of Sand Dune Subrange II_B	Kabutonuma Area				Formation of Sand Bar	Formation of Sand Bar; Magome and Ōmori Shell Mounds				Eruption of Mt.Nantai
	3000	Middle			Formation of Sand Dune Subrange II_A	Volcanic Activities; PERIOD OF SAROBETSU LAGOON								Accumulation of Organic Clay	
II	4000	Early				Accumulation of Corbicula bearing Silty Clay				Formation of Yurakucho Beds					Buried Fraxinus 5678± 700
	5000	Eariest		+6.5	Formation of Sand Dune Range I Formation of Hooked Sand Spit			Paleo-Ishikari Bay II	Period of Paleo-Kushiro Bay	Formation of Numa Bed; Maximum Stage of Transgression			Change Zone I	Formation of Paleo-Kano Bay	
	6000				Erosion of Hōtoku Upland	Accumulation of Marine Silty Clay									Beginning of Accumulation of Peat
	7000		Increasing Warmth	Transgression		PERIOD OF SAROBETSU SEA									Formation of L.Paleo-Oze II
		Pre-Jōmon Period													Mudflow
I			Cold			Accumulation of Basal Peat		Formation of Basal Humus Beds		Formation of Basal Humus Beds Egota Conifer Bed					Accum. of Old Peat Filling-up of L.Paleo-Oze I

ferred to the Yayoi period such as the Yamaki and Mamanoue relics are also known at Toro near Shizuoka, Urigō near Toyohashi and so on. The geological section of Mamanoue shows that the environments when human beings were settled were different from these before or after that time. Why did the peat layer accumulated only at that time? The author considers this cause is that floods did not affect the areas of Mamanoue and Yamaki at that time. Probably at that time floods would not have occurred so frequently as before. Indeed, that time was the fourth peat bog forming period. This assumption does not disagree with the age of the relics. Would the decrease of floods be considered as a cause which brought the possibility of the rice culture in the Yayoi period?

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